MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. VI, PART 1.

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GEOLOGICAL SURVEY

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INDIA.

VOL. VI.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR-GENERAL OF INDIA IN COUNCIL,

UNDER THE DIRECTION OF

THOMAS OLDHAM, L. L. D.,

Fellow of the Royal and Geological Societies of London; Member of the Royal Irish Academy; Hon. Mem. of the Leop.-Carol. Academy of Natural Sciences; of the Isis, Dresden; of the Roy. Geol. Soc. of Cornwall: Corr. Mem. of Zool. Soc., Lond., &c., &c.

SUPERINTENDENT OF THE GEOLOGICAL SURVEY OF INDIA.

CALCUTTA:

PRINTED FOR THE GOVERNMENT OF INDIA.

SOLD AT THE

GEOLOGICAL SURVEY OFFICE,

OFFICE OF SUPERINTENDENT OF GOVERNMENT PRINTING,

AND BY ALL BOOKSELLERS;

LONDON: WILLIAMS AND NORGATE.

MDCCCLXIX.

CALCUTTA:
OFFICE OF SUPERINTENDENT OF GOVERNMENT PRINTING,
1869.

NOTICE.

The Sixth Volume of THE MEMOIRS OF THE GEOLOGICAL SURVEY OF INDIA, now issued, will be found to contain papers descriptive of large areas of country in different parts of India. These relate chiefly to Western India, but there are also detailed descriptions and maps of two of the smaller detached Coal-fields of Bengal. Full osteological details are also given of the interesting remains of Frogs, long known to Geologists as occurring near Bombay; and of which the Survey has been fortunate in obtaining some well preserved specimens recently exposed by engineering works undertaken in that locality for reclamation purposes.

The present Volume gives a description of the Geological Structure of about sixty thousand square miles of country,—an area larger than that of all England and Wales. It is not intended to convey the idea that our examination of this immense area has been sufficiently detailed or close to justify its being considered final—(this would have been impossible within the time which has been devoted to it),—but I believe that this examination has been carried out as carefully, and recorded in as full detail, as was practicable with the very imperfect topographical maps which we had at our disposal. The nature and value of these will be found noticed in the several papers, now published.

The structure of quite as extensive an area of country adjoining that herein described will be noticed in the next volume of the Memoirs, now in preparation.

CALCUTTA,
December 1868.

THOMAS OLDHAM,
Supdt., Geological Survey of India.

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NOTE *on the Geology of the neighbourhood of* LYNYAN *and* RUNNEEKOTE, *North-West of* KOTREE, *in* SIND, *by* WM. T. BLANFORD, *Assoc. Roy. School of Mines; F. G. S., Dy. Supt.; Geol. Survey of India.*

ERRATA.

This paper having been printed in the absence of the writer, a rather serious error has crept in at p. 3. The foot note with a list of fossils does not refer to the place indicated by the asterisk, but to line 6 from the top in the next page. The fossils were obtained from the yellow limestone there described as forming the top of the scarp near Lynyan.

The following errata are of minor importance:—

Page 9, 3rd line, from bottom, *for* '4564' *read* '456.'
„ 10, 19th line, from top, *for* 'the total thickness in the neighbourhood; the limestone' *read* 'the total thickness; in the neighbourhood the limestone' &c.
„ 11, 13th line, from top, *for* 'number' *read* 'member.'
„ 18, 10th line, from bottom, (Cutch paper), *for* 'series. In' *read* 'series, in.'
„ 18, 14th line, from top, and p. 25, 2nd line, from bottom, *for* 'Vol. II' *read* 'Vol. V.'

Report in 1863.

so far as the prospects of finding coal were concerned, were detailed in a Report to the Government of Bombay dated December 23rd, 1863, a portion of which is appended. As that Report, however, was designed solely to explain the reasons for the unfavorable opinion expressed of the economical value of the

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CONTENTS.

1.—INTRODUCTION.

The following slight contribution to our knowledge of the geological structure of Sind is the result of a visit paid in November 1863 to the country immediately north-west of Kotree on the Indus, the present terminus of the Sind Railway, for the purpose of examining the locality at Lynyan, whence an inferior kind of coal (or rather of lignite) was extracted in 1858-59; and of determining, so far as was practicable in a brief visit, whether there was a probability of the existence of other deposits of fossil fuel in the neighbourhood. The results of the visit, so far as the prospects of finding coal were concerned, were detailed in a Report to the Government of Bombay dated December 23rd, 1863, a portion of which is appended. As that Report, however, was designed solely to explain the reasons for the unfavorable opinion expressed of the economical value of the

Object of visit.

Report in 1863.

deposits, the geology was only cursorily referred to. The object of the present remarks is to describe at somewhat greater length the sections examined, and to point out briefly their bearing upon our previous knowledge of the geology of Sind.

Present report.

The only previous observer who has left any record of the geology of the neighbourhood of Kotree is Captain Vicary, who traversed part of the country rapidly on his march from Kotree to Sehwan.*

2.—TRACT OF COUNTRY EXAMINED.

It is first necessary to state how far my investigations extended.

Leaving Kotree I marched up the river bank to Bhada, about 10 miles. The alluvium, west of the river, is here very narrow, and immediately beyond it there arise low hills of white compact limestone, abounding in *Alveolina.*

Route.

From Bhada I marched 15 miles north-west to Lynyan. After remaining there for two days, I marched about 30 miles further to the north-west to a gorge in the Eri Hills at a place called Rani-ki-kot or Runneekote. So far the journey, except at one place between Bhada and Lynyan, had been across a broad plain. Runneekote is in the first high range of the hills which border the plain to the west. The plain is known as the Vira; the hills as the Eri range.

From Runneekote I returned due east to the Indus, about 15 miles: and thence dropped down the river in a boat to Kotree.

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* Quarterly Journal of Geological Society, London, Vol. III, p. 341. In Vol. VI of the Journal of the Bombay Branch of the Royal Asiatic Society, p. 182, Dr. Carter described a series of geological specimens from the Lynyan, illustrating a section of the rocks forwarded by H. Inman, Esq., who superintended the works at the colliery. Mr. Inman, in his sections, represented the rocks forming the hills at the sides of the valley as resting unconformably upon the deposits associated with the coal. I could not see the alleged unconformity distinctly, and found that Mr. Inman, in his section, which I saw, had exaggerated the dip of the valley beds.

3.—Geological observations.

It should be remembered that the following notes were for the most part taken during a hurried journey, and, consequently, that many important matters may have escaped observation.

From Bhada on the Indus, the road to the north-west for a short distance passed over alluvium, then over a ferruginous gravel, somewhat resembling laterite and probably a modern formation. The first distinct rock seen is limestone containing *Foraminifera,* and although less compact than the alveolina-limestone of Kotree, almost unquestionably a portion of the same bed*. Calcareous sandy beds, white or varie-

* The following fossils were obtained from this bed in a few hours' search. The determinations are by Dr. Stoliczka:—

Mollusca.

Gastropoda.

Terebellum distortum, *d'Archiac.*
Actæonina sp.
Terebra Flemingii, *d'Arch.*
Natica decipiens, *d'Arch.*
„ longispira, *Leymerie.*
Cerithium, sp.

Lamellibranchiata.

Gastrochœna sp.
Spondylus 2 sp.
Nerita (Velates) Schmideliana, *Chemnitz.*
Ostrea Flemingii, *d'Arch.*

Brachiopoda.

Terebratula sp.

Articulata.

Echinodermata.

Hemiaster digonus, *d'Arch.*
Eurhodia Morrisi? *d'Arch.*
Eurhodia sp.
Echinolampas sp.
Temnopleurus Rousseaui, *d'Arch.*
Cidaris, spines.

Cœlenterata.

Corals.

Cyclolites Vicaryi, *d'Arch.*
Stylocœnia sp.
Trochoseris sp.
Montlivaltia sp.
Trochocyathus sp.

Protozoa.

Foraminifera.

Operculina canalifera, *d'Arch.*

gated, succeed, and the road, about five or six miles from Bhada, descends a rather steep scarp of variously coloured limestone and shale. The scarp continues, not regularly but broken into hills, on the right hand of the road as far as Lynyan. There it consists at the top of rubbly limestone of a yellow colour, abounding in fossils, but this limestone appears to be rather lower than the white alveolina-limestone which forms the top of the scarp further south.

Beneath the limestone there is first a band of calcareous sandstone abounding in *Ostrea Flemingii*, next a sandy bed, and then coarse calcareous sandstone, with ill preserved casts of cones and other marine fossils. These beds are horizontal, or nearly so.

Below the beds of the scarp a series of sandstones and clays of very various colours come in, mottled-grey, or red, often ferruginous, containing gypsum in abundance in places, and in others having an efflorescence of alum on the surface. These beds roll slightly at varying angles, never appearing to dip at more than 5° or 6°, and generally at not above 2° or 3°. No marine fossils could be found; carbonaceous markings and imperfect plant remains, too ill preserved for identification, are not uncommon.

Lignite.

Amongst these beds the lignite occurred, which was worked at Lynyan. It was a small patch, not extending above 100 yards in any direction, but 5 feet 9 inches thick where first worked. The lignite was excessively pyritous, and liable to spontaneous combustion.

Vira plain.

Across the Vira plain but very few rocks are seen. The greater part of the surface is covered with pebbles, chiefly of the rocks forming the hills to the west. Rounded fragments of alveolina-limestone and of silicified wood abound.

Wherever rocks do emerge, however, they are invariably, so far as I saw, the gypsiferous clays and sandstones, and there appears no reason to doubt that these underlie the whole plain.

At the foot of the hills the compact alveolina-limestone comes in upon the beds of the plain; it is slightly disturbed, and the junction is much concealed by immense accumulations of boulders and gravel, the beds of which are arranged in terraces at the places where water-courses emerge from the hills.

Eri Hills.

The outer range of the Eri Hills runs approximately north and south, and, where I visited it, it is double: a lower ridge bordering the plain, and a loftier ridge, about 1,000 feet in height, running parallel, about two to three miles further west; through both these ridges a gorge is cut by the Mohun River at Mohun-kot or Rani-ki-kot, or Runneekote, a peculiar old fortress of the Ameers of Sind*.

Gorge at Runneekote.

At the entrance to the gorge the limestones, where they emerge from beneath the alluvial boulder deposits, have a low dip to the east. They are sharply twisted up at one spot, but continue steadily beyond and rise into a hill about 460 feet high.† From beneath them, at the west base of this hill which is part of the outer ridge already mentioned as bordering the plain, the gypsiferous clays and sandstones crop out, much varied in colour as usual, but with a very high dip of 60° to the eastward. Yet there is no clearly marked unconformity. These beds continue at the same dip for above a quarter of a mile, when they roll over at an anticlinal, and continuing up the stream to the westward lie at much lower angles, frequently nearly horizontal, but generally dipping at 10° or 15° to the west or north-west. At the axis of the anticlinal the lowest bed seen is *trap*, which only appears in the stream for a few yards. It is slightly amyg-

* The place is said to be the only spot along the range where sweet water is procurable, and this doubtless led to its being fortified, especially as the gorge is well defended by nature.

† By aneroid measurement.

daloidal and contains agates, and it has a slightly stratified appearance. Only a few feet of thickness are seen. The sandstones resting upon it do not appear to be in any measure altered by the contact.

Trap in Mohun stream.

Below about 20 feet of solid trap, there appears, on one side of the Mohun stream (in which alone the igneous rock is exposed), a shaly bed, perhaps an ash. It is this which tends to give the trap so markedly stratified an appearance. It is possible that this lower bed may be sedimentary, and belong to the same series as the variegated sands and clays above the trap, and that the latter is simply interstratified. So very small a section is seen that these questions must be left undecided for the present.

Beyond the anticlinal the variegated sands and clays continue for 1 mile or 1½ miles to the west, then, just beyond the lower part of the kot, the inner ridge crosses from north to south, parallel with the outer ridge, and, like that, composed of alveolina-limestone resting upon the sands and clays. In neither case does there appear reason to suppose the existence of any fault between the limestone and the underlying beds. Yet it should be noticed that, in neither case, is there any appearance of the rubbly calcareous beds so rich in marine fossils which rest upon the sands and clays of the Lynyan.

Inner ridge, &c.

The inner ridge slopes away to the west, a valley succeeds, and beyond that other limestone ridges are seen, which, however, I did not visit. They appear to consist of rocks dipping to the west, and, consequently, resting upon the limestones of the kot, but it is unsafe to depend upon such distant observations.

The thickness of the beds seen at Runneekote was approximately as follows:—

Limestone, abounding in Alveolina	1,000 feet.
Variegated sands and clays	1,300 „
Trap	20 „

From Runneekote to the banks of the Indus, in a direct line, no rocks were seen, the whole surface being covered and concealed by the alluvial pebble deposit.

4.—Relations and classification of beds.

The deposits of this portion of Sind were considered by Captain Vicary* to be the following in descending order :—

1. Conglomerate.
2. Clays and sandstone.
3. Upper bone bed.
4. Sandstone; fossils rare.
5. Lower bone bed.
6. Coarse arenaceo-calcareous rock with *Cytherea exoleta?* and *exarata*: *Spatangi*: no *Nummulites*.
7. Pale arenaceous limestone with *Hypponyces*, *Nummulites*, and *Charoideæ*.
8. Nummulitic limestone of the Hala Range.
9. Black slates; thickness unknown.

The first five are probably higher beds; indeed the first six are excluded by Dr. Carter as Miocene†, but Captain Vicary‡ states that the rocks of the hills north-west of Kotree are in all respects similar to the non-nummulitic rock No. 6. Captain Vicary traversed this country very rapidly, and the difficulty of procuring water prevented him from visiting the hills. He mentions, however, the occurrence of "variegated clay abounding with gypsum, but containing no fossils," and again states that between the range of hills stretching north to Sehwan (Eri [illegible]) and the Indus, "there are numerous low hillocks of aluminiferous clay," and he mentions his inability to ascertain the relations of these clays to the beds of the higher ranges. In the hills north-north-west of Kotree he recognised his No. 7, probably, in the beds so rich in marine fossils noticed by me near Lynyan.

* Quar. Jour. Geol. Soc. London, III, 335.

† Summary of the Geology of India in 'Geological Papers on Western India,' page 698. In a note, page 743, however, he follows D'Archiac and Haime in classing all beds below the bone-conglomerate as Eocene.

‡ Quar. Jour. Geol. Soc. London, III, 341.

My visit was so hurried, and I had so little previous acquaintance with the nummulitic rocks of Western India, that I can only indicate the opinions to which I should incline, especially as they appear to differ slightly from Captain Vicary's. If, as appears probable, the limestone of the Eri Range be the No. 8 of that officer's section, I am disposed to believe it the equivalent of the rocks of Kotree, but which Captain Vicary referred to his No. 6 (see appended sections). This, however, is a subject which requires further investigation. Still the circumstances, that the limestone of Kotree is exactly similar in character to that of Runneekote, that both abound in *Alveolina,* and that both overlie the same series of sands and clays without, at least, any great unconformity, are strongly in favor of their identity. The absence of the highly fossiliferous beds seen east of Lynyan at Runneekote does not necessarily prove unconformity between the sands and clays of the Vira plain and the alveolina-limestone; the lower portion of the latter in the Eri Hills may represent the yellow limestone of Lynyan.

It is, however, very probable that a break in the series exists between the clays and sands and the alveolina-limestone. The latter is not only marine, but probably a deep-sea deposit. The sands and clays are not only deficient in marine fossils, but they abound in the remains of plants; and if they are not of fresh-water origin, they must be estuary or coast accumulations. The limestones of Lynyan, on the other hand, were not necessarily deposited in very deep water; many of the contained shells are shallow-water forms.

If, then, there be a break in the series between the limestone and the underlying beds, the age of the latter remains to be determined. The only recognisable fossils which I met with were some leaves of plants in a bed of argillaceous shale at Runneekote. They were all dicotyledonous, which is in favor of the tertiary age of the clays and sandstones.

It remains to indicate the representatives of these rocks elsewhere. Though they appear to be unusually widely diffused, the information afforded as to their age is not great.

In Cutch, aluminiferous clays and "marls of every variety of colour" are stated* by Captain Grant to occur near Mhurr. Although he classed these beds with his coal-bearing series, which, in places at least, is jurassic, these alum-bearing beds, occurring close to the border of the nummulitic limestone, may not improbably represent the variegated clays and sandstones of Sind. The mass of the coal-bearing Cutch beds are probably older.†

Similar beds of clay and sand containing gypsum and lignite underlie the nummulitic limestone of the Punjab salt range.‡ They vary in thickness from about 3 feet in the east to 300 feet and more in the west. (Dr. Oldham). Dr. Fleming states, loc. cit., p. 333, that near Kuttha and Moosakhail arenaceous limestone containing nummulites and other fossils common to the limestone above is interstratified with them. If this be the case of course they form an integral portion of the nummulitic series. Mr. Theobald gives a section at Kolki, (l. c., p. 668,) showing that some carbonaceous alum-shales are interstratified with the lowest beds of the nummulitic limestone. All observers agree that the shales and sands with lignite rest upon jurassic beds. In their mineral character, as described by all observers, and their position beneath the nummulitic limestone, they correspond so exactly with the Sind beds, that but little doubt can exist of their representing the latter.

It appears probable, therefore, that this series of variegated clays and sands has a considerable extension to the north and north-east. It is unnecessary to enter into the question of their further extent at present

* Geol. Trans., London, 2nd Ser., Vol. V, page 295. † See Notes on Cutch.

‡ See Dr. Fleming, Jour. Asiatic Soc., Beng., XXII, pp. 333, 4564, &c., W. Theobald, Jr., Jour. Asiatic. Soc., Beng., XXIII, 658, 666. Dr. Oldham.—Memo. on the results of cursory examination of the salt range, &c., 1864.

in this direction. There are, however, some remarkable and interesting points connected with the sections of similar rocks examined by Dr. Carter in Arabia.* Compare, for instance, the sections at Muskat, Masira, and Marbat.

At Muskat the section is (abridged from the two sections given by Dr. Carter).

Coarse limestone with foraminifera.

Siliceous limestone.

Argillaceous strata with gypsum, calcareous sandstone, variegated sands, and pebble beds.

Greenstone and Serpentine.

At Masira—

Compact limestone with foraminifera	100 feet.
Coarse yellow limestone	50 „
Sand, and red and green arenaceous clays traversed by veins of gypsum	50 „

It does not appear that the base of the last named bed was seen, so this is not necessarily the total thickness in the neighbourhood; the limestone is said to rest on diorite.

At Marbat—

White limestone strata containing alveolina, besides other fossils	1,400 feet.
Argillaceous strata of a red colour	300 „
Coarse micaceous sandstone of a yellow colour becoming finer as we ascend	1,700 „

From the sketches these beds possibly rest upon igneous rocks, stated to comprise granite, greenstone, and diallage rock or euphotide.

* Memoir on the geology of the south-east coast of Arabia. Journal Bombay Branch Royal Asiatic Society—IV, 21, and Geological Papers on Western India, p. 551.

Similar sections occur in other places, and are described at length in Dr. Carter's valuable memoir. It is unnecessary to do more than refer to them here. In his "Tabular arrangement" of the strata, at the end of his paper, he refers all the argillaceous strata to the lower cretaceous period, and classes the limestone containing *cyclolina* and *alveolina* as upper cretaceous. If I understand his opinions correctly, he considers the Muskat and Masira sections as higher than the other, and while the first are believed to be eocene, the latter is classed as cretaceous.* In his "Summary of the Geology of India" (2nd Edition), however, he distinctly states that "this marl or clay, or sandy deposit, which underlies the 'nummulitiferous limestone at Muskat, Masira, on the mainland of Arabia, in Cutch, and in Sind," is the lowest number of the nummulitic series.†

It is out of place here to enter further into the discussion of the relations of these beds; it is sufficient to show that in Arabia, as in Sind and the salt range, beds of clay and sandstone immediately underlie the nummulitic series. But the most interesting point is the fact of these clays resting on diorite and euphotide. As Dr. Carter occasionally

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* Geological Papers on Western India, p. 699.

† From the manner in which Dr. Carter's publications appear in the 'Geological Papers on Western India,' with merely scattered annotations, it is not always easy to learn what his final opinions were. But at page 700, in a note, he allows that the evidence on which he had mainly relied for the cretaceous age of the rocks of the Marbat scarp, *viz.*, the presence of *cyclolina*, stated by D'Orbigny to be a cretaceous form, is insufficient. He had previously* described a species of *cyclolina* from the Buran River near Jerruck, in Sind, and noted its resemblance to the species occurring in Arabia. In both cases it was accompanied by *alveolina*. There can be very little doubt of the Sind beds being tertiary, and in all probability, the very similar beds of Marbat and other localities in Arabia are equally so. The distinctively mesozoic fossils, as *ammonites*, appear to have been only found in the lowest part of the sandstone, which may be of distinct age from the argillaceous beds at the base of the limestone. At the same time the circumstance of that limestone being of nummulitic age does not prove the argillaceous beds to be newer than mesozoic.

* Jour. Bombay Br. R. A. S., V. p. 140.

refers to some of the traps of Western India under the name of diorite, it is not clear whether his diorites of Arabia be really that rock, or coarsely crystalline dolerites.

The peculiar interest attaching to any igneous rocks immediately underlying beds associated with the nummulitic series arises from the fact of that series having been found by me both near Surat and in Cutch* to rest unconformably upon basaltic rocks belonging to the great trap series of Western India. How far that series, so marvellously developed in Hindoostan, can be traced to the westward, and to what degree it is connected with the various volcanic rocks of the Arabian Peninsula, is a question of peculiar geological interest.

5.—General conclusions.

Finally, I have only to recapitulate the principal conclusions at which I have arrived, and to point out one or two of the most interesting questions for future explorers in Sind to determine; the conclusions are—

1*st*.—The lowest bed of the nummulitic limestone north-west of Kotree in Sind rests upon a considerable thickness of gypsiferous clays, and sands, variegated in colour, producing alum and containing lignites. These are similar to beds underlying nummulitic limestone both in the Punjab and in Arabia.

2. The lowest of these beds seen rests upon trap.

The questions are—

1*st*.—Are the nummulitic limestones conformable to the gypsiferous sands and clays?

2*nd*.—Do the latter belong to the nummulitic formation, or are they older?

3*rd*.—Does the underlying trap belong to the same series as the great trappean formation of Western India?

September 1866.

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* See subsequent paper.

Extracts from report on the Coal or Lignite of Lynyan or Lynah, and the neighbourhood, in Lower Sind.

So much information upon the coal of Lynyan (Lyneah, or Lynah, &c.), near Kotree in Lower Sind, has already been comprised in previous Reports, especially in those by Mr. Blackwell (dated 30th April 1858), and by the Committee under Major Malcolm (dated 22nd February 1861), that it is quite unnecessary for me to describe either the coal itself or the place where it is found in any detail, and my remarks need only be brief, since, after a careful examination of the locality, I have arrived at conclusions similar to those formed by the gentlemen who preceded me.

* * * * * * * * *

After staying for two days at the old colliery, and examining the neighbourhood in several directions, I went on to Runnee-ki-kot (about 30 miles north-west of Lynyan), in the hills. His Excellency the Governor had directed my attention to the spot as probably affording sections of the same beds as those associated with the coal at Lynyan. This I found to be the case, and I was enabled to examine the formation at much greater advantage from the excellent manner in which the strata were exposed on the banks of a stream traversing the hills.

At Lynyan I descended the old shaft, and succeeded in penetrating a few feet into the workings. They had, however, fallen in to so great an extent that I could do little more than enter them.

The practical value of any coal formation may be considered to depend, provided it is easily accessible, upon three principal points :—

1st.—The quality of the coal in the seam or seams discovered.

2nd.—The quantity, that is, the thickness and extent, of those seams.

3rd.—The existence of other workable seams of coal overlying or underlying that known to occur.

1st.—The Report of Major Malcolm's Committee deals so fully with the quality of the coal which was formerly obtained from the Lynyan colliery that I could have added but little even had my means of judging been equal to those possessed by the members of the Committee, which they were not, in consequence of the mine having been abandoned for some years. I cannot help believing, however, that practice on the part of the Engineers in the river steamers and of others burning the coal, with some simple modifications of the fire grates used, might have overcome some of the difficulties attending its employment. The most serious objection was the large quantity of iron pyrites, and its consequent excessive liability to spontaneous combustion.

2nd.—The seam, where opened out by Mr. Inman, was 5 feet 9 inches thick. In the well sunk by the Beloochees, in which the coal was first discovered, it is said to have been 7 feet thick, but this appears rather doubtful, for in the plans prepared by Mr. Brunton the underground workings are shown to have been stopped near the well (which lies to the eastward of Mr. Inman's shaft), in consequence of the coal thinning out. It is also shown in Mr. Brunton's plans, and stated in his letter, that the workings were stopped on the north

and west at about the same distance, which is very small—not more than 25 yards at the outside; while to the south-east the thickness first discovered held good in January 1859. But the level in this direction was intended to intersect the first deep shaft (No. 1) sunk by Mr. Inman, and in that shaft, as clearly shown by Mr. Brunton's sections, the coal had diminished in thickness to such an extent as to have been passed through without being recognised by Mr. Inman, who continued sinking for nearly 50 feet further, upon the supposition that the coal seam, instead of being nearly horizontal, dipped at an angle of 20° or 25° to the south, an error from which a slight acquaintance with Geology might have saved him, since the rocks are sufficiently well seen at the surface close by, and, although varying somewhat in their dip, they never exceed about 7°, and even that dip is exceptional. Where the clays accompanying the coal crop out at the surface, 250 or 300 yards south-west of the colliery, the coal is only represented by a slightly carbonaceous shale.

The distance of the shaft No. 2, from which the coal was worked, from shaft No. 1, is only 100 yards. The whole workable "seam" of coal was, in fact, exhausted. And, as dry details seldom convey a sufficiently distinct impression to any one who has not visited the place, it may suffice to state that *the patch of coal at Lynyan, for it cannot be called a seam, did not extend in a workable form for a stone's throw in any direction whatever*. Further remark is superfluous.

Mr. Brunton, in his letter of the 15th January 1859, suggests the probability of the coal supposed to exist at the bottom of No. 1 shaft being the representative of the lower seam passed through in the well sunk by the Beloochees. From the absence of all who had been concerned in the mining operations at the time of my visit, I could not learn whether any coal was ever found at the bottom of No. 1 shaft, but if it was it certainly did not represent the lower bed in the Belooch well, which was only 12 feet below that worked, while the bottom of No. 1 shaft, only 100 yards distant, was 50 feet below the same bed.

3rd.—The above, however, is not new. The same facts have been detailed, and the same opinions expressed, in previous Reports, and I believe that the principal object of my being deputed to examine the locality was to endeavour to ascertain whether there is a probability of other beds of coal of better quality and more persistent thickness being discovered in the neighbourhood. I very much regret to be obliged to report that I do not see a prospect of such being met with.

I searched for a considerable distance around the old mine without finding in the small ravines any indication of outcrops of coal. Doubtless far closer and wider search than mine has been made with the same result. Several pits were sunk in the neighbourhood by the Officer of the Railway Company in 1859, in only one of which, so far as I could learn, coal was met with, and then it was only one foot in thickness.

In order to explain my reasons for disbelieving the existence of workable seams of coal beyond the area thus explored, I must briefly describe the geology of the district.

* * * * * * * * *

The thickness of the variegated sandstones and shales exposed on the section of Runnee-ki-kot is not less than 1,200 feet; and the greater portion of this thickness is repeated two or three times by the rolling over of the beds. Only in one place could I detect any-

thing like the outcrop of a bed of coal, and then it was very irregular, of small thickness, and appeared to thin out within a very few yards. But not only is the thickness of this bed irregular, but the same is remarkably the case with many of the small beds of shale which occur. In fact here, as at the Lynyan, the rocks generally are irregularly stratified and variable in thickness. Moreover, the more shaley, and especially the more carbonaceous beds, so abound in iron pyrites that they are largely dug out by the Beloochees, and exposed in damp places, for the purpose of manufacturing alum from them, the production of the alum being due to the presence of the sulphur of the pyrites.

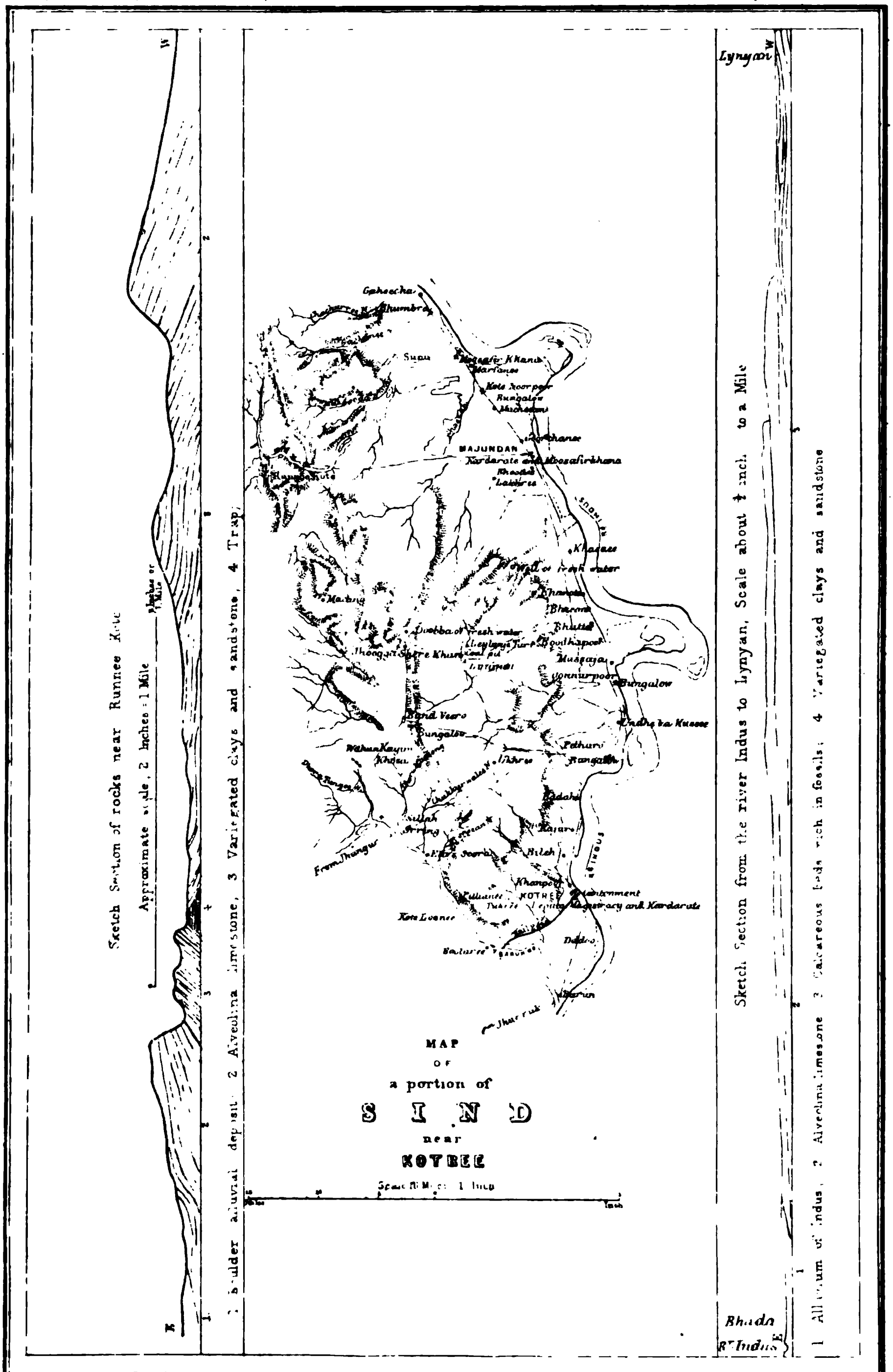
Were a coal bed discovered in such a position, there could be scarcely a doubt but that it would abound in iron pyrites, and that it would thin out within a short distance; in fact it would be precisely similar to that formerly worked at the Lynyan, and equally worthless.

As, therefore, this formation preserves the same characteristics over a distance of at least 30 miles, there appears every probability of its peculiarities being characteristic and persistent throughout, and those peculiarities are inconsistent with the occurrence of seams of workable coal.

Excessive irregularity, and, in general, the abundance of iron pyrites, are, indeed, notoriously characteristic of the numerous deposits of coal which have from time to time, and in various parts of India, been discovered in the Nummulitic formation.

* * * * * * * * *

Bombay,
The 23rd December 1863.



Lith by H M Smith, Calcutta, Decr 1866.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the GEOLOGY *of a portion of* CUTCH, *by* WM. T. BLANFORD, *Assoc. Roy. School of Mines;* F. G. S.; *Deputy Superintendent, Geological Survey of India.*

CONTENTS:

The large proportion of these memoirs which has been devoted to the remarkable groups of plant-bearing formations, associated with beds of coal in various parts of India, will show how continuously the attention of the Geological Survey has been given to these deposits. A summary of the information obtained up to 1860 and 1861 respectively will be found in Mr. Oldham's two papers 'On the Geological relations and probable Geological age of the several systems of rocks in Central India and Bengal' (Vol. II, page 299), and 'Additional remarks on the Geological relations, &c., &c.' (Vol. III, page 197).

Of the several divisions into which the various formations have been classed, the two most important are those for which the Survey has adopted the names—DAMUDA and RAJMAHAL. The age of the former was shown to be, probably, upper palæozoic, that of the latter to be mesozoic, and, possibly, 'not newer than the lower Oolite.'

In the papers just referred to, the different localities in India, in which this Rajmahal series had been identified, were stated to be—1st, Rajmahal Hills in Bengal; 2nd, near Trichinopoly, in the Madras Presidency; 3rd, in the Province of Cutch, Western India; 4th (very doubtfully), near Jubbulpoor, in Central India. The flora of this last locality (the 'Upper Damuda' or 'Jubbulpoor' beds* of the late Mr. J. G. Medlicott) was shown to be different from that of the true Rajmahal and its relations were doubtful. The presence and abundance of *Palæozamia* and other Cycads were the chief characteristics of this series, wherever seen.

It was in Cutch that these beds and their peculiar fossils were first observed. A paper by Captain Grant in the Transactions of the Geological Society of London (2nd Ser., Vol. II, page 289) contains a rather detailed account of the geology of Cutch, and is accompanied by an excellent geological map of the province. The plant fossils obtained were described by Morris, the animals by Sowerby.

The peculiar circumstance which renders the Zamia-beds in Cutch of unusual interest is their association with rocks containing marine fossils of undoubted Jurassic age. In every other locality, except Trichinopoly,

* These beds were described by the late Mr. Medlicott in his paper, 'On the Geology of the central portion of the Nerbudda District' (Mem., Geol. Survey, India, Vol. II,) under the name of 'Upper Damuda.' The separation was made and the name given on good geological grounds, and it was at first thought that the beds represented the 'Rajmahal group' of Bengal. But further examination of the fossils showing a distinction from the latter, while it equally showed a marked separation from the 'Damuda' ('Lower Damuda') series. In subsequent MSS. reports, Mr. Medlicott adopted for the beds which he had first named 'Upper Damuda' in the Nerbudda valley, the name 'Jubbulpoor,' the rocks being well developed near that town. No very large series of fossil plants was obtained, and even those procured have not as yet been sufficiently examined and compared; while Mr. Medlicott's own researches (which, being incomplete, have not been published) showed the probability of several distinct groups of beds existing between the true Damudas and the Mahadevas in the upper parts of the Sone valley. The exact relations of the so-called Jubbulpoor beds are, therefore, still doubtful. Mr. Oldham also informs me that more recently-obtained specimens throw a doubt on the identity even of the Palæozamia, said to occur in the 'Upper Damuda' of the Nerbudda valley with either of the true Cutch species.

the Rajmahals and their representatives are unaccompanied by beds of definite geological date, and the discovery of the relations of these rocks to the cretaceous beds of Ootatoor in Trichinopoly district, Southern India, only rendered it more desirable to ascertain correctly what was the connection between them and the Jurassic marine series. The Cutch representatives of the latter were described at some length by Captain Grant in the paper already referred to, but he left the question of the relations between the Oolitic beds, which he termed the 'laminated series or Upper Secondary,' and the Zamia-bearing beds, his 'sandstone and clay with beds of coal' somewhat obscure. It will show the state of knowledge of the subject, previously to the observations I am now going to describe in detail, to quote the passage in Captain Grant's report, which treats of the relative position of the 'Upper Secondary formation' (that is the beds with jurassic fossils to the other strata. Captain Grant writes*—

"I searched diligently to find the relative position of this forma- "tion (Upper Secondary) distinctly defined, but in vain, as, at its ap- "parent junction with other beds, the whole of the strata were broken "up, and so confused as to baffle every attempt to ascertain the boundary. "I am induced, however, to believe that it occupies hollows in the sand- "stone and coal formation, or abuts against it. It cannot underlie that "series, because its strata are always *horizontal*, except where locally dis- "turbed; while the beds of sandstone and coal are as invariably in- "clined at a considerable angle, and are everywhere intersected with "dykes, slips, and other dislocations, from which the Upper Secondary "strata are generally free. In one instance, the formation evidently "occupied a hollow in the coal sandstone.

"In many places it appears to abut against the sandstone, occupy- "ing large tracts which may, at some period, have been covered by beds "of that formation, subsequently washed away. From what has been

* l. c. page 297.

"stated above, it is at all events newer than the coal beds; and this "conclusion is also borne out by its imbedded fossils".

It will be perceived that the opinion given is by no means decisive, no case being quoted where the two formations were actually seen or traced into contact. It was, therefore, highly desirable that a more careful examination of the Cutch section should be made, in order to put an end to this doubt. However, until the Survey was extended to Western India, at the close of 1862, the great distance of Cutch from all places where the surveyors had been engaged prevented any examination of it from being made. In the following year (November 1863), an opportunity occurred. I had been deputed to Sind, at the request of the Government of Bombay, for the purpose of examining the reported coal of Lynyan,* and when returning to Bombay, instead of going directly from Kurrachee, it was decided that I should go round the coast to Mandavee in Cutch: I then spent about a fortnight in a rapid traverse of the country.

2. *Route followed.*—From Mandavee I went through Bhooj to Jooria on the banks of the Runn, devoting a day on my road to the examination of Katrore hill, in the Charwar range. From Jooria, I marched westwardly along the edge of the Runn to Charee, and thence I re-crossed the province from north to south to Mandavee, whence I proceeded to Bombay. I thus examined two sections of the rocks which occur in the province, and which appear to have, throughout the greater portion of Cutch, a general dip from north to south (see section).

Before proceeding to give the conclusions at which I arrived, and which differ to an important extent from those of Captain Grant, it will be well to state in detail the observations upon which they are founded. It should be borne in mind that the special object of my visit being to trace out the relations between the Jurassic marine beds and those containing Zamiæ, my whole time was devoted to this object, and facts

* See preceding paper.

bearing on other questions were merely noted when they presented themselves. Some most interesting points relating to the tertiary formations yet await enquiry.

3. *Detailed observations.*—Leaving Mandavee and marching on the road to Bhooj, a plain of alluvium is traversed as far as Asambya. There ferruginous clays are seen, which harden on the surface into a form of laterite. These, from their mineral character, may be recognised as identical with the lowest beds of the nummulitic formation near Surat.* Beneath the laterite at Asambya is a peculiar bed of sandy clay, excessively ferruginous, and containing masses of impure hæmatite, and below this again pale dove-coloured sandstone with red bands, and with deep red clay in the jointing planes. In their ferruginous character and variation of colour these beds recall somewhat the variegated clays and sandstones of the Lynyan and Mohun in Sind.† They are, however, so far as seen, of small thickness.

All these beds dip south at a low angle (about 5°). Immediately from beneath them to the north, trap crops out, dipping also to the south beneath the tertiary beds. It continues for about four miles, the dip being the same all the way. Somewhat to my surprise, I immediately recognised in it the trap of the Deccan and Guzerat. The steady bedding and the mineral character were both unmistakeably identical, the latter especially, for, amongst the different beds, there occurred not only the characteristic amygdaloid of the Deccan traps, with its kernels of stilbite surrounded by a crust of green earth, but also the very peculiar felspar porphyry so common locally amongst the volcanic formations of Western India.

The road from Mandavee to Bhooj crosses the strike of the trap beds diagonally, and, just beyond the village of Choolri, coarse white and brown sandstones come in beneath it, still dipping south. About

* These will be described in a future paper.

† See preceding paper.

Megpoor, white argillaceous sands, purple and brown fine thin-bedded sandstones, are met with, recalling, in mineral character, the Trichinopoly plant beds. All this tract is included by Captain Grant in his 'sandstone and clay with coal', and from this neighbourhood were derived the fossil plants described by Mr. Morris, and already referred to.*

Similar beds, horizontal or rolling, but with a general low southerly dip, extend to the Charwar range, a low ridge of hills which crosses the country from east to west about five miles south of Bhooj. This range is escarped on the north side, and slopes very gradually away to the south. At the "ghat" on the road to Bhooj, the rocks are horizontal on the crest of the hill, but on the north side they dip 10°, or 15° to south and south-west. The inclined beds are sandy shales and thin sandstones, varied in colour, white, grey, brown or purplish, and containing imperfect plant remains in abundance. At the North base of the hill are blueish-grey shales and hard thin calcareous bands, also with fragmentary plant remains.

This range of hills is coloured as belonging to the "Laminated series" by Captain Grant, and I have heard, from other sources, of *Ammonites* being found upon it. I could not succeed in finding any at this spot, but I saw fragmentary plant remains in nearly all the beds.

Sandstone and argillaceous beds continue to Bhooj, having, in general, a low southerly dip, not exceeding 2° or 3°. A sharp dip is seen here and there; one is met with just north of the blue shales at the foot of the ghât. A similar sharp twist was observed south of the range between the villages of Shirat and Bharapoor. There is frequently much oblique lamination in the sandstones.

Katrore hill lies about 12 miles south-east of Bhooj. It is a portion, in fact, of the Charwar range, which, to the east, is less defined than south of Bhooj. Along the north side of this hill, and of those

* Geol. Trans., 2nd Ser., Vol. V, explanation of Plate XXI.

adjoining, I found marine beds containing *Ostrea Marshii*, two species of *Pecten*, *Trigonia costata*, *Belemnites*, &c. These beds dip towards the south, but in places, close to the foot of the hill, they were much disturbed and even in places vertical. There is certainly a twist, possibly a fault, along the base of the hills here, but if there be a fault of any great dimensions, it is certainly less clearly indicated than might have been expected.

In the rocks of Katrore hill itself, near the summit, *Ammonites* of two or three species occur in red concretions, which are scattered throughout a soft grit. Other similar concretions contain fossil wood. The beds dip steadily S. 30°-40°, W. at about 5°.

North of Bhooj, for a considerable distance, the coarse sandstones and argillaceous beds of the Zamia-bearing series are met with. An attempt was once made to work a bed of coal which crops out in a nulla at the village of Toombo. The section seen in the nulla is—

		Ft.	In.
1.	Coarse brownish and white sandstone very false-bedded ...	12	0
2.	Ferruginous sandstone	0	6
3.	Coarse white false-bedded sandstone, with carbonaceous streaks, especially abundant towards the base ...	2	0
4.	Ferruginous parting	0	1
5.	Coarse white and yellowish sandstone, false-bedded and containing carbonaceous streaks in places	4	0
6.	Carbonaceous shale, passing down into	1	0
7.	Coal	1	4
8.	Blue clay with carbonaceous markings	0	0

The middle 8 inches of the coal is very inferior, being rather a shale than coal. Only about 8 inches is really good; this is bright and firm coal.

Some hundreds of feet of white and brownish sandstone, with occasional shaly or ferruginous bands, underlie the little section above detailed. The predominating rock is coarse white sandstone, much false-bedded. Plant fragments abound, but nothing was met with sufficiently preserved for identification.

The above will show the kind of rocks of which the beds associated with the coal are mainly composed.

North-west of Bhooj, on the road to Jooria, white and brown sandstones prevail at first, then blue pyritous shales, and thin calcareous and sandy bands with some gypsum. A good section of the latter is seen where the path crosses the Khari stream; they continue, however, for some distance, and some hills, coloured by Grant as marine, appear to be composed of them. All have a low dip of 3° to 5° to south and south-east. No trace of plant remains was detected, but marine fossils were not found before reaching Dhosna, where some fragments contained *Belemnites*.

Beyond this village, coarse white, purple and brown sandstones in thick beds come in, still with the same dip and apparently underlying the marine beds of Dhosna. These rocks resemble those associated with the coal north of Bhooj. To them succeed, still apparently in descending order, ferruginous beds with marine fossils. The low southerly dip is constant till within two miles of the Runn, when the beds with marine fossils turn sharply over, and dip to the north-east at from 10° to 30°.

Just south of Jooria, there is apparently the same anticlinal: beds abounding in marine fossils dip at very high angles.

Very little rock indeed is seen along the Runn from Jooria to Charee. The low lying tract traversed is a portion of the Bunnee (which has no such definite boundary as is represented on the map), and appears to be alluvial.

Charee is the locality whence a large proportion of Captain Grant's fossils were obtained. The villagers showed me the spot from which they were taken: the beds are of calcareous sandstone, dipping in a semi-circle from a small trap hill, called Kira hill, the general direction being to the east. Marine fossils are very numerous, several kinds of *Ammonites*, *Belemnites*, and forms of *Ostrea*, *Pecten*, *Nucula*, *Pholadomya*, *Trigonia*, *Rhynchonella*, *&c.*, being conspicuous.

The dip of the beds is from 10° to 30°. They pass, apparently, under a series of beds, between Charee and Jogee Arul, in which marine fossils are scarce, though occasionally occurring; the mass of the beds being white and brown sandstones with variegated sandy clays. Fragmentary plant remains are met with in shaley beds at Jogee Arul.

From Jogee Arul, I visited the trap hill Denodur, called a volcano.* Thence to the southward coarse sub-horizontal sandstones prevail with numerous isolated hills of trap, apparently intrusive. At Kukkurbit, I found, at length, in some carbonaceous shale, vegetable fossils sufficiently well preserved to be distinguishable. The following could be recognized :—

CYCADEÆ.—*Palæozamia Cutchensis*, Morris : very abundant.
acutifolium, Morr.
Bengalensis, Oldham.

CONIFERÆ.—*Brachyphyllum ?* † *sp.* common.
Taxodites ? sp. new.
Small *Walchia* like stems (perhaps *Lycopodites affinis*, Morris).

FILICES.—*Tæniopteris sp.* fragmentary, (it may be *T. ovalis*).
Sphenopteris ? sp. common.

There is no change in the rocks south of this, until the traps are reached just south of Seesagud. The latter are precisely the same there as further to the east; they dip in the same direction, and must be of very nearly the same thickness. At Syree lateritic clay comes in resting upon the trap as at Asambya. It is conglomeratic, containing fragments of trap, scoriaceous lava, sandstone and clay. Above it are yellow and brown clays, all more or less ferruginous, and white sandstones with

* It is really a mass of intrusive trap, and may be the nucleus of an old volcano, but most certainly it is not a volcanic cone, and the stories of its having been in a state of eruption in 1819 are fictions. Captain Grant, although he considered Denodur a volcano, disbelieves these tales.

† It is, I think, possible that a badly preserved specimen of this plant may have been the *Fucoides dichotomus* of Morris. Geol. Trans., 2nd Ser., Vol. II, Pl. xxi, Fig. 7. It closely resembles a species equally abundant in the Jubbulpoor beds and may be identical.

ferruginous bands, and a little further south, at Badye, limestones appear containing fossils, chiefly *Pectens* and other bivalves. No *nummulites* were met with.

Here alluvium comes in. Indeed, no continuous section was seen except close to the trap.

4.—*Discussion of results. Jurassic beds.*—It will be noticed that the general dip of the beds throughout the portion of Cutch traversed is, as has already been observed, to the south. There is much local disturbance, but no indication, so far as was seen, of any great faulting. Still such may occur, and may so seriously complicate the beds as to render all conclusions as to their relations uncertain. But the dips are, in general, so steady, and there are such large tracts of the country free from any important disturbance, that I believe perfectly sound deductions may be made from the observations above detailed, and that no great error will be incurred by viewing the whole north and south section of the rocks exposed from the broken anticlinal on the banks of the Runn to the alluvium near Mandavee as a simple ascending series of beds. It is particularly worthy of notice that no great and sudden change of mineral character takes place anywhere north of the trap boundary, such as might be expected in a break of sequence between marine and fresh water beds.

The lowest beds seen in Cutch appear to be the marine fossiliferous beds of Jooria and Charee.* South of Jooria these distinctly pass beneath the white and brown sandstones of Bakria and Dhosna, the Charee rocks pass upwards equally clearly into the plant-bearing series of Jogee-Arul, and the fossiliferous marine formations of the Katrore hill and Charwar range dip steadily beneath the Zamia beds to the south. So

* The beds of the islands in the Runn, the Putchum, and Kureer, shown in Captain Grant's sections to dip to the south, may be lower than the Jooria beds, but they are well known to be marine, and are represented as such in Captain Grant's map. I had not time to visit them.

far, then, from Captain Grant being correct in considering the Jurassic marine beds the newest, they most distinctly dip everywhere beneath the Zamia beds. But there are many indications that the Zamia beds in places dip under marine fossiliferous deposits. It has been shown that the sandstones of Bakria, which seem clearly to underlie the marine beds of Dhosna, precisely resemble the beds associated with coal at Toombo in mineral character; and the rocks of the plain of Bhooj appear to underlie the marine strata of the Charwar hills. There is, however, one possible circumstance to be borne in mind, that is, that there may be a great fault with an up-throw to the south along the north scarp of the Charwar hills, and that the marine rocks of the range may be simply those of Jooria and Charee brought up again by that fault, and in favour of this view there is the evidence of disturbance to which I have already adverted. I think, however, if this were the case, that the range would be better defined, and that better evidence of the fault, which would be some thousands of feet in throw, would be seen in the excellent sections of the rocks exposed at the base of the hills south of Bhooj. All that I saw in the way of disturbance did not appear to indicate any such extensive dislocation.

The whole evidence, I think, is in favour of the intercalation of the marine beds with the Zamia-bearing sandstones and clays, and of such intercalation being more frequent towards the base of the series than higher up. The position of the band of fossiliferous rock of the Charwar range, thinning out both to the east and west, as represented in Captain Grant's map, is in favour of this view. The general strike also favours the idea of the marine beds north-west of Bhooj replacing and representing the sandstones associated with the coal to the north-east. It is true that both of these may be explained by faulting. But there is one circumstance which should be mentioned, as it added strongly to the evidence upon which I founded my opinion of the intercalation of the two groups. Captain Shortt, the Political

Agent at Bhooj,—to whose kindness and assistance I was much indebted for aid in traversing the country,—gave me a slab of ferruginous sandstone, containing *Ostrea Marshii* and other marine fossils, which he had found forming part of a bed close to the town of Bhooj. He took me to the spot, but we did not succeed in finding the exact stratum, the rocks being much concealed by sand. However, sandstone precisely similar in appearance, although unfossiliferous, occurred in other beds close by, and they were unquestionably intercalated in the sandstone and shaly beds of the plain on which the town stands. These beds are marked by Captain Grant as belonging to the Zamia-bearing series, and I believe he is perfectly correct, as they have the characteristic mineral character of that formation.

But even if the apparent intercalation should prove, on closer examination, to be due to faulting, I still think there is every probability that all the rocks, both marine and Zamia-bearing (the last being probably fresh water) belong to one general series, the age of which is clearly marked by the marine fossils. The sole argument of any weight alleged by Captain Grant in favour of the more recent age of the marine beds was certainly founded in error, and I cannot help thinking that Captain Grant may have been misled by his memory, when he wrote of the greater general horizontality of the marine strata, when compared with the beds associated with the coal. Of course my observations having been very much less extensive, I cannot speak very positively, but amongst the places I visited were all Captain Grant's principal fossil localities, and at all of those, singularly enough, the marine beds were much disturbed. At Charee, as I have shown, the most fossiliferous beds dip at 10° to 30°. At Jooria the dip is 30°, and even more in places, and there is a sharp anticlinal, and, at the base of Katrore hill, I found *Ostreæ* and *Trigoniæ* abundant in beds dipping at from 50° to 80°. Now the usual dip of the Zamia beds does not exceed 5°; doubtless, they are disturbed in places, and dip at high angles, but the marine

beds, as I have shown, exhibit quite as much evidence of disturbance subsequent to their formation.

From the list given above of the fossil plants found at Kukkurbit, it will be seen that there are some identifications, not previously known, with the flora of the Rajmahal beds. All the three *Palæozamia* are found in both series, and of the two ferns, both are, probably, identical with Rajmahal forms.*

Of the age of the marine fossils no question can arise. A very large proportion are well known and typical European species, the remainder are closely allied to European forms, the greater portion being characteristically Lower Oolitic. My collections contain several species not included in Mr. Sowerby's lists of Captain Grant's fossils. As, however, I hope Dr. Stoliczka, who has already examined the collections made by me, will give descriptions of them, and as he will, doubtless, treat the subject of their representation in the European formations at length, I shall not dwell further on the subject. It is possible that some of the marine intercalations may differ in age, and that the beds of Katrore hill and the Charwar range may be rather more recent than those of the beds bordering the Runn.

Before concluding, a few remarks may be made upon the other formations of Cutch. These are the tertiary beds and the nummulitics, the traps and the newer alluvial deposits.

Tertiary beds and Nummulitics.—It has been shown that the tertiary beds, north of Mandavee, rest upon the traps, and that they contain rolled fragments derived from those rocks. The junction is doubtless quite unconformable. In the part of Cutch which was traversed, no nummulitic limestone occurs, so that the relations of that rock with the

* These being only found in small fragments, a positive identification has not been possible, but, so far as they go, the probability is that both are identical with forms occurring in the Rajmahal beds.

tertiary beds* of Captain Grant could not be determined. The 'tertiary beds' were distinguished by Dr. Carter, in his Summary of the Geology of India, as Miocene, but Messrs. D'Archiac and Haime in the "Faune Nummulitique de l'Inde"† class both 'Tertiary beds' and Nummulitic limestone as Eocene, and show that, in Sind, the fossils of the one are accompanied by the Nummulites of the other. Dr. Carter, in a note to the second edition of his 'Summary' in the Collection of Geological Papers on Western India, p. 743, accepts the same view. At the same time, Messrs. D'Archiac and Haime‡ point out the probability of a separation of the Eocene strata into different sub-divisions, characterized by distinct fossils.

The circumstance that all the fossils described by Sowerby from the nummulitic limestone appear to have been distinct from those found in the (non-nummulitic) tertiary beds of Cutch, renders it probable that some division may be made. But this must await further examination.§

Traps.—I have already stated that the basaltic rocks of Cutch are perfectly identical in mineral character with those of Malwa, Bombay, and the Deccan; that they are bedded and consist of a series of flows, unquestionably, as I believe, sub-aerial in their origin. The chief point in which, in Cutch, they are distinguished from the trap flows of the Deccan is in their aggregate thickness, which, in Cutch, appears to be about 1,800 feet.|| In the Deccan it is only known that it greatly exceeds twice that thickness. Whether the diminished amount is due to the denudation undergone in Cutch previous to the deposition of the tertiary

* At the time that Captain Grant wrote, nummulitic limestone was generally considered pre-tertiary.

† Pp. 358, 359. ‡ l. c. p. 359.

§ It will be shown that there is probably a difference between the upper portion of the series of beds newer than the traps, and the lower portion which is associated with nummulitic limestone near Surat, and this distinction probably holds good elsewhere.

|| Their outcrop extends over four miles of country, and their dip averages 5°.

rocks, or whether the traps were originally of smaller vertical extent in this country, is a subject on which no opinion can be at present expressed.

So far as my examination extended, the traps rested upon the Jurassic beds. If any traps are interstratified with the secondary formations, as Captain Grant states,* they must belong to a distinct series from the Deccan and Malwa traps, and consequently,—if I am correct in identifying the two—from the principal masses seen in Cutch, for the Malwa traps, as will be shown in a future paper, rest unconformably upon the middle cretaceous beds of Bagh, and must therefore be of much later age than the Jurassics of Cutch.

Throughout a portion of the Jurassic area, as shown by Captain Grant, small hills of trap abound. They appeared to be intrusive and are very probably the nuclei of outbursts of the Deccan and Malwa trap period, and from them may have proceeded the lava flows which intervene between the Jurassic and Nummulitic formations.

Alluvial Deposits.—As in many other parts of India these fringe the coast which is said to be constantly gaining. The most important development, however, of these deposits in Cutch appeared to me to be the Runn, which I am disposed to consider the bed of an inlet of the sea filled up by the accumulation of detritus brought down by the rivers. It is just at present in the debateable state, water part of the year, land another part, but every year must increase the height of the land surface, and consequently diminish the depth of the water at the period of the overflow. Of course the whole may be an area of depression, but further proofs of this are necessary than the fact of a small portion having been sunk, and another part raised, by the earthquake of 1819.

* Geological Trans., 2nd Series, Vol. V, page 312.

5. *Conclusions.*—It only remains to point out the principal conclusions at which I have arrived. These are—

1*st.*—That the lowest beds seen in Cutch were Jurassic marine beds, and that these were beneath beds containing *Palæozamia.*

2*nd.*—That there are good grounds for supposing the marine Jurassic and the Zamia-bearing beds of Cutch to be intercalated, and that there appear even stronger reasons for believing them to belong to one general series. The only doubt as to their intercalation arises from the possibility of repetition by faulting. If not intercalated, the marine beds are certainly the older. It follows as a corollary, that all beds in India containing *Palæozamia acutifolia,* and *P. Cutchensis,* in other words, those belonging to the Rajmahal group of the Survey classification, are of Jurassic age, and probably, Lower Jurassic.*

3*rd.*—That the Deccan and Malwa traps extend as far to the west as Cutch, and that they there rest upon Jurassic beds and are covered unconformably by nummulitic formations.

A sketch section is appended, which, if compared with that given in the Geological Transactions, will illustrate the differences between my views of the geological structure of Cutch and those of Captain Grant. On the accompanying map of the portion of Cutch traversed by me, the geological lines are from my own observations. These agree closely with those given by Captain Grant.

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* See Appendix.

APPENDIX.

In the preceding pages Mr. W. Blanford has detailed the observations which have led him to conclusions, regarding the geological succession of the beds containing marine fossils identical with those occurring in other countries in the jurassic series and of the plant-bearing beds found in the same area with them in Cutch, exactly the opposite of those to which the examination of the same district had led Captain Grant in 1836.

That observer believed that the 'sandstone and coal' of his classification were lower in position and older than his 'secondary' limestone and shale, in which he had found abundance of oolitic ammonites and other fossils. He believed both to be of the same general age, 'oolitic,' but his description, though not at all definite, led to the idea that there had been a considerable interval of time between the deposition of the 'sandstone and coal' series and the formation upon these of the 'secondary' limestones. As pointed out many years since, there was, however, much doubt still remaining on this point. Mr. Blanford's more recent researches have led him to believe that in places these plant-bearing beds are in all probability actually intercalated with the marine fossiliferous deposits, but that if not so (which is possible), they certainly are younger than these marine beds, not older, as Captain Grant had represented them.

The age of these marine fossiliferous beds was defined at the time of the publication of Captain Grant's researches (1837) as about that of the lower oolite of England, 'the whole series of molluscous remains indicating a period extending from the cornbrash to the great oolite.' Such was the accepted view of all who had examined their relations. Mr. Blanford's small collections, although his very brief visit did not enable him to devote much time to such purposes, have added

some important evidence to that already known, and we therefore give here a complete list of all those species obtained by him which admitted of specific identification. Such as could only be determined generically have been omitted, as being useless for any purposes of comparison.

Specially characteristic species are marked with an†, while in a separate column I have given other localities in India, where several of the species are known to occur.

List of FOSSILS *collected in* CUTCH *by* MR. W. T. BLANFORD, *determined by* DR. F. STOLICZKA.

NAME.	Locality in Cutch.	Other Indian localities.
† Belemnites canaliculatus, *Schloth.*	Charee.	Niti: Spiti. Salt-range.
„ var. Bessinus, *D'Orb.*	Charee.	
Nautilus hexagonus, *Sowerby,*	Charee.	
Ammonites alatus, *Strachey,*	Charee.	
„ armiger, *Sow.*	Jooria.	
„ arthriticus, *Sow.*	Katrore Hill.	
„ Braikenridgii, *Sow.*	Katrore Hill.	Spiti.
„ calvus, *Sow.*	Charee. Shapoor.	
„ corrugatus, *Sow.*	Charee.	
„ elephantinus, *Sow.*	Charee.	
„ fissus, *Sow.*	Charee.	
„ formosus, *Sow.*	Charee.	
† „ Herveyi, *Sow.*	Charee.	Salt-range.
„ ignobilis, *Sow.*	Charee.	
„ Kudernatschi, *Hauer.*	Charee.	
† „ macrocephalus, *Schloth.*	Charee.	Spiti: Niti. Nepal.

List of FOSSILS *collected in* CUTCH,—*continued.*

NAME.	Locality in Cutch.	Other Indian localities.
Ammonites maja, *Sow.*	Charee.	
„ opis, *Sow.*	Charee.	
„ Pottingeri, *Sow.*	Charee. Katrore Hill.	
„ Sabineanus, *Oppel,*	Charee.	Spiti : Niti.
„ Spitiensis, *Blanford,*	Jooria.	Spiti : Niti.
„ torquatus, *Sow.* (non *Blanf.*)	Katrore hill.	
Aptychus lamellosus, *Schloth.*	Jooria.	
GASTROPODA.		
† Amberleya capitanea, *Münster,* sp. (Turbo).		
† Pleurotomaria agathis, *Desl.*	Jooria.	
Trochus bellona, *D'Orb.*	Charee.	
PELECYPODA.		
Astarte compressa, *Sow.*	Jooria.	
„ pisiformis, *Sow.*	Charee.	
„ rotunda, *Sow.*	Jooria.	
„ hiemalis, *Stoliczka,*	Charee.	Kibber, Spiti.
† Avicula inæquivalvis, *Sow.*	Jooria.	Gieumal.
Gervilia acuta, *Sow.*	Jooria.	Parang Pass.
† Lima pectiniformis, *Schloth.*	Charee.	
Mytilus furcatus, *Goldf.*	Charee.	
Nucula cuneiformis, *Sow.*	Charee.	Spiti.
„ tenuistriata, *Sow.*	Charee.	
† Opis similis, *Sow.*	Jooria.	
Ostrea carinata, *Lamk.*	Charee.	
„ hastellata, *Schloth.*	Charee.	

List of FOSSILS *collected in* CUTCH,—*continued.*

NAME.	Locality in Cutch.	Other Indian localities.
† Ostrea gregarea, *Sow.*	Charee.	
„ Sowerbiana, *Bronn*, (ap. Keyserling) ...	Charee.	
† Pholadomya inornata	Charee.	
† Plicatula flabelliformis, *Sow.*...	Charee.	
„ pectiniformis, *Sow.*...	Charee.	
† Trigonia costata, *Sow.*	Charee.	Gieumal.
„ pullus, *Sow.*...	Jooria.	
BRACHIOPODA.		
† Rhynchonella concinna, *Sow.*	Charee.	
„ insignis, *Sow.*	Charee.	
„ Morieri, *Desh.*	Charee.	
„ obsoleta, *Sow.*	Charee.	
† Terebratula biplicata, *Sow.*	Jooria.	
† „ carinata, *Sow.*	Charee.	
† „ Sella, *Sow.*	Charee.	

As it is hoped that only a short time will now elapse before the district of Cutch can be more carefully and more widely examined, and more extensive collections made, any attempt at a full discussion of the relations of these beds to European groups had better be deferred. Taken as a whole, the Cutch beds form a group which is obviously on the same geological horizon as the 'Dogger', corresponding principally with the *Bajocien* and *Bathonien,* and partly with the *Callovien* of European Geologists.

The geological age of the marine fossiliferous beds may thus be accepted as tolerably defined. If the plant-bearing beds be really intercalated with these, as Mr. Blanford thinks probable, the age of the latter must also be accepted as defined. But unfortunately this point is

still left undecided. In any case Mr. Blanford thinks it clear that if not intercalated, they are younger than these Dogger* beds. This being established, it follows as a matter of course that the argument as to their probable age, based on Captain Grant's descriptions, fails, and that the relations of these beds in Cutch prove (not, as argued by me in 1860, that the plant beds were 'not more recent than the lower oolite,' but) that these beds are not older than the lower oolite. This is an important step.

The identity of the distinctive and most abundant fossils of the Rajmahal group of Bengal with those occurring in these beds in Cutch was shown so long since as 1854† and again in 1860, and the necessity for at once admitting the same age for both established. Nothing whatever to invalidate this has been since discovered, and whatever geological horizon be established for the beds with plants and coal in Cutch must be admitted also for the Rajmahal series of Bengal. This was then (1860) shown to be decidedly pre-cretaceous, and now it is shown to be, if not really lower jurassic, at least not older than the lower oolite. I am not aware that any writer has viewed them as other than jurassic.

Mr. Blanford (p. 2) refers to the beds in the Nerbudda valley at first supposed to be equivalents of the Rajmahal beds of Bengal and Madras. There is strong reason for thinking that this supposed equivalence is not supported by the fossils. It was never strongly insisted on; it was said that these beds contained "many forms not represented in the Rajmahal group," and with similarity in several, identity of only one was stated.‡ Our specimens are few, and many not very well preserved, and until further research has been undertaken in the Jubbulpoor country, I cannot admit, as established, the equivalence of the Jubbulpoor beds with the typical 'Rajmahal' group.

Since the publication of my sketch of the 'geological relations of the rock systems of Central India and Bengal' in 1860, the occurrence

* Mem. Geol. Survey, India, II, 322.

† Jour. As. Soc., Bengal, XXIII, 272, 1854.

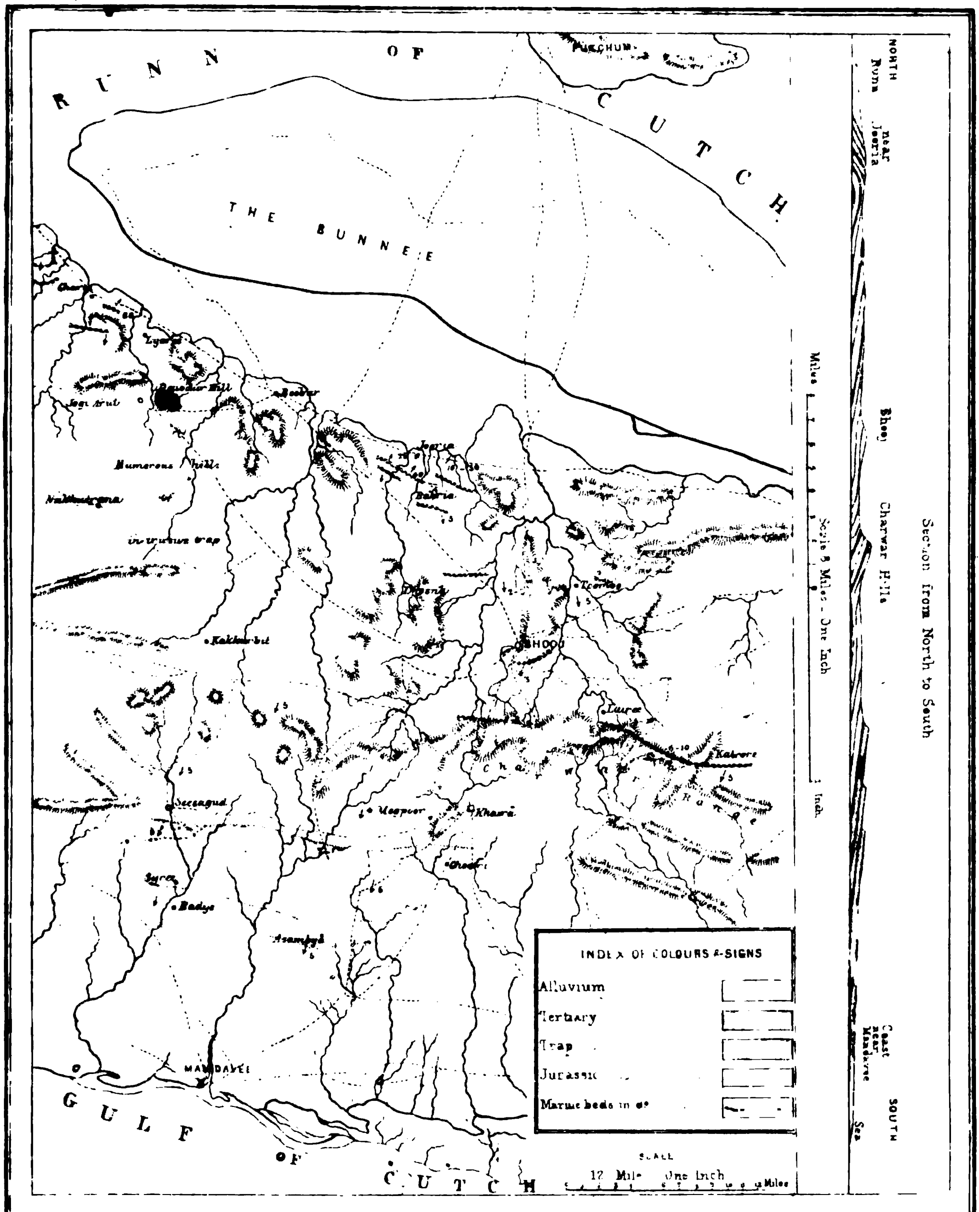
‡ Mem. Geol. Survey, India, II, 324.

of rocks of the same general character as those described has, in Southern India, been traced from the Trichinopoly district northwards for more than five degrees of latitude. These rocks invariably occur in small isolated patches, all but denuded away, and resting on the uneven surface of the old crystalline gneiss and other metamorphic rocks. Their identity can in almost every case be established not only by the strikingly constant mineral character which they present, but also by the almost invariable presence of plant remains of several species, clearly identical with those in the typical Rajmahal beds. Every thing, therefore, has tended to establish the conclusion arrived at in 1859, that these South Indian beds were unquestionably of the same geological age as the Rajmahal group. And, if this be established by the researches in Cutch to be lower jurassic, the Madras Palæozamia-beds must be admitted to be of this age also.

As I have just stated, this has not yet been definitely ascertained; all that is proved is, that they are not older than this. Captain Grant originally thought them representatives of the oolitic coal of Yorkshire. Morris, when first describing these Palæozamia, pointed out the great interest attaching to them from their striking analogy with Stonesfield-slate fossils. D'Archiac (Hist. des. prog. d. l. Geologie, VII, 624) pointed out the confusion in Captain Grant's description, but accepting his statements referred the plant-bearing beds to the horizon of the 'lower sandstone and shale' of Phillips' divisions of the oolite, and the same lower jurassic age has been accepted as established by several subsequent writers. It is not improbable that further research may fully establish this conclusion. But there are several curious anomalies in the flora of this Rajmahal series which prevents my admitting this age as established up to the present. I should prefer leaving the point open, admitting only this general conclusion, that the Rajmahal series of Indian Geology must lie between the bottom of the cretaceous system and (? the top of) the lower jurassic group.

T. OLDHAM.

February, 1867.



Lith. by I. M. Smith Calcutta, Decr. '8

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. VI, PART 2.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

The BOKARO COAL-FIELD, *by* T. W. H. HUGHES, *Associate, Royal School of Mines;* F. G. S., *Geol. Survey of India.*

CONTENTS.

I. GENERAL TOPOGRAPHY.

The River Bokaro, whose valley extends along the foot of the southern scarp of the Hazareebagh plateau, gives its name to this coal-field. Mr. Williams, the first who ever geologically examined this portion of the basin of the upper Damoodah, conferred the title, for the reason that the River Bokaro flows for a distance of 27 miles through the field, and is the stream of greatest importance draining the area to which this report refers. Perhaps it would have been better, however, if he had chosen the name of the lofty hill of Loogoo to indicate the field. Standing, as the hill does, in the middle of a plain, and rearing its summit far above any other eminence in the neighbourhood, it is the most prominent natural object which meets the eye for miles around, and could never fail to attract attention to itself.

Loogoo hill.

Position of field.

The portion of country occupied by the Bokaro Field is comprised between 85° 30′ and 86° 10′ east longitude, and 23° 40′ and 23° 50′ north latitude, and covers an area of 220 square miles. Its greatest length is in an east and west direction, and is about 40 miles; its maximum breadth from north to south does not exceed 6½ miles.

Boundaries well marked by hills.

The boundaries are distinct and well marked. Bordering the field to the north is a chain of hills composed of gneiss rising in some instances to a height of 3,000 feet above the level of the sea. This continues unbroken from the eastern to the western extremity of the field, and then sweeps round, taking a north and south direction, cutting off the coal measures on the west. This chain is not an independent one, but is connected with the Hazareebagh table-land at intervals, where the activity of the denuding forces has been less than at other places.

The southern boundary is formed by another range of hills; not nearly so conspicuous and elevated a chain, however, as the northern one.

Physical appearance.

The physical appearance of the area constituting the field is, in the main, of that type which repeated confirmation over a large extent of country has now established as invariably characterising those regions occupied by the true coal-bearing strata and their associated rocks. The Talchir, the middle and upper divisions of the Damúda Series, and the Lower Panchéts, uniformly produce a level surface, whilst the Barákar or lowest group of the Damúda Series, and the Upper Panchéts, as constantly give rise to massive hills, and rapidly succeeding hillocks and dales.

The special feature of each formation is in this field admirably exhibited, and the wide expanse of the main body of the coal measures contrasts forcibly with the imposing mass of sandstones and conglome-

rates of the Upper Panchéts constituting Loogoo Hill, which stands out boldly in the middle of the field, dividing it into two nearly equal portions.

Measure of degradation.

Nothing can more fully impress the geologist with an adequate sense of the immense power of river-erosion than this hill. Exhibiting to view an accumulation of 1,500 feet of sedimentary strata, above the level of the Bokaro and Damoodah Rivers, we have this enormous thickness representing the *minimum* amount of degradation which this area has undergone. The appearance of the hill is bold and picturesque, presenting on all sides abrupt precipitous falls. A great charm is added to its scenery by the numerous deep and narrow gorges that exist in it, through which purling streams find their way; and the monotonous stillness around, so eminently distinctive of Indian jungles, is broken at intervals by the many little noisy cascades which rush over the edges of the massive beds, wherever there are sudden falls in the level of the stream-courses.

The whole country is well wooded; and great stretches of rich foliage occur. Loogoo Hill, and the higher peaks of the Hazareebagh table-land, furnish much excellent timber; and so brisk is the demand at present that the most inaccessible crags are scaled, in order to procure the *sissoo* and *sál*, which are the two varieties of trees most sought after. A considerable profit accrues to those zemindars who, fortunately for themselves, possess the right of felling timber; but the indiscriminate manner in which cutting is being carried on is very much to be regretted.

Drainage.

The drainage of this area is effected almost entirely by the Bokaro River, which falls into one of the principal tributaries of the Damoodah—the Koonar. This latter stream passes through only a small portion of the eastern part of the field, and joins the Damoodah opposite the village of Khetko. Its geolo-

gical interest is marred by the imperfection of its section, and the almost total absence of any exposure of coal along its banks diminishes its importance for our purposes.

Bokaro.

The principal river in fact is the Bokaro; and its northern and southern water-sheds are the only ones in connection with the physical geography of the district, which exclusively (or nearly so) belong to the field. The northern water-shed is identical with the outer scarp of the Hazareebagh table-land, of which Jeeloonga (Jilúnga) Hill is the highest point. The largest body of water furnished to the Bokaro is derived from the area to the north of it. Its feeders, however, are few and small, drying up at the commencement of the cold weather, so that the Bokaro never contains any large volume of water, except during the rainy season.

Water-sheds.

The southern water-shed is very faintly indicated (if we except Loogoo Hill) by slightly rising ground between the true river valleys of the Bokaro and Damoodah.

General geology.

There is a superior interest attaching to this area, as compared with the Jherria District, from the fact of the development of a higher series of rocks, and from the discovery of, and confirmation of, apparently unconformable overlap between the several groups and formations which occur here. Hitherto our classification has been in a great measure one dependent upon lithology, although not purely so; and it is a matter of congratulation that this is now borne out by collateral evidence of a less arbitrary kind.

The area occupied by the field is excessively narrow. Coincident with this, we find that the strata occurring within its limits are highly disturbed in many places, and that flexuring and faulting exist to so large an extent that the stratigraphical relations of the beds become greatly confused and complicated.

In an assemblage of rocks showing, generally speaking, such slight deviation from original horizontality as those of the coal measures, excessive contortions and inclinations of the strata, and the faulting therewith connected are due to the localisation of yielding, through irregularity of resistance, to wide spread forces. The runs of quartz-breccia through the metamorphic series, indicating faults, were possibly at one time within the limits of the coal measures, although now far outside their boundary, and no doubt the pressure excited during the period of the formation of these faults aided materially ,or pre-determined, those derangements of which we shall speak in the following pages. When endeavouring to resolve some of the difficulties which beset us relative to the boundaries of this field, we must constantly bear in mind the secondary effects due to local compression accompanying faults, as well as those which are the direct result of that active power to which upheaval and depression of large tracts of country are owing.

The series represented are the—Talchír,—Damúda,—and Panchét; and I now propose to enter immediately into details regarding their lithological characters, distribution, and relations.

II. Talchir Series.

Talchír Series.

The area occupied by this series is limited in the present field. Little patches crop out every here and there from under the Damúdas in the eastern part of the field, displaying the well known characters of the formation. The thickness of beds exposed in the various sections varies from a minimum of about 20 feet to 100 feet and more. Outliers on the metamorphic rocks are numerous, and may be met with in any part of the country in the vicinity of the field. The hilly nature of the ground between Ooparbundah and Gobinpoor and the want of detail on the maps almost preclude the possibility of any one successfully indicating every small spread of Talchírs; very few, however, I believe, have escaped detection, and even if they

have, it matters little, as they are probably only a few square yards in extent and consequently much too minute to be laid down. Within the main boundary of the field, the Talchírs are first met with near Tarrumbee, represented merely by the bottom-conglomerate, which here possesses a green matrix much more siliceous than argillaceous in its composition.

Barákar scarps.

South of Peepradeeh and from thence west to Amlo and Karo, the pebble beds of the Barákars form two, and sometimes three, nearly parallel scarps at the foot of which the Talchírs stretch near Chepree; this series is better exposed here than elsewhere in the east of the field. The conglomerate bed still occupies its normal position, and above it a light yellowish, pale brown sandstone occurs.

Inlier.

An inlier of metamorphic rock is seen on the road from Dhoree to Chepree. The Talchírs to the north of it dip away at an angle of 25°, but soon become nearly horizontal; those south of it are inclined at 8° and 10°.

The line of boundary curves much owing to the irregular manner in which denudation has occurred. It is natural up to Chepree, and as far as Gobinpoor, where a cross fault shifts the rocks to the north. The Talchírs, as will at once be seen by inspecting the map, are overlapped in many places; and west of the Koonar are only seen as outliers beyond the main body of the field, until we approach the villages of Mando and Indra-Jarbah, where, owing to the removal of the overlying group, a thickness of about 500 feet of strata of this series is exposed, and each distinguishing feature is recognisable. In the Boodah stream a typical section is visible: the conglomerate underlying all, and then the acicular clays (needle-shales), and very fine-grained sandstones succeeding. The needle-shales are not so conspicuous as they were in the Jherria Field, and their place is in a great measure taken up by sandstone, similar to that noticed near Chepree.

The Boodah nuddee is joined by a tributary north of Gobinpoor, in which the sandstones just mentioned are exhibited from top to bottom. The varieties of colours which they present are most striking; and many of them being ribboned, they produce, when properly selected and well arranged, a most pleasing effect. At present (1866) these sandstones are being quarried to a considerable extent for flooring-stones in the barracks at Hazareebagh.

Mr. Williams, when speaking of the Talchírs in this part of the field, assigns to them a thickness of 1,000 feet. This is far too much, the beds are rolled in several instances, and so become repeated. The dips, generally speaking, are slight, but they vary up to 8°, 14°, and even 25° near the boundary.

The structure of the series is very simple, and agrees, on the whole, with the section seen in the Jummoonee in the Jherria field. The following tabulation shows the order and succession of the beds of which it is composed (ascending) :—

1. At the base, conglomerate.
2. Fine-grained sandstones with occasional bands of conglomerate.
3. Fine-grained sandstones, of varying colours, with intercalated beds of 'needle-shales.' These make up nearly the entire series.
4. Fine-grained sandstones, and one or two conglomerate bands.
5. Fine-grained massively bedded sandstones.

Some of the boulders in the conglomerate resting upon the metamorphics are of enormous size. One of the largest which I measured was 42 feet in circumference. Outliers occur beyond the limits of the field in the western portion of our area, just as they do along the northern boundary. They rarely consist of more than the conglomerate which forms the base of the group.

Relations of the Talchírs.

The lithology of the Talchírs has been so often described, and their characters so often dwelt upon, that I have thought it quite needless to enter upon a repetition of facts with which those who have studied Indian

Geology in even a very slight degree are well acquainted. The relations of the Talchírs, however, is a subject not yet worn out. With regard to the conditions under which the series was deposited, I wish to say a few words, as it has some bearing upon the view which we shall take of the overlapping of the Talchírs by the Damúdas. If both series were deposited under similar conditions, it would scarcely be fair to argue that overlap indicated unconformity; whereas if the conditions under which they were formed were distinct, we should have some reason for assuming this, even though we had not the direct evidence in a vertical section of denudation of the one series having occurred previously to the deposition of the other; which would, of course, immediately settle the question.

The Damúdas are assumed to have been accumulated under similar conditions to those of the coal measures of England. Possibly such may be the case. The Talchírs, however, are probably marine. Every circumstance is against their being fresh water deposits; the immense area which they occupy and the continuity and constancy of character of their beds being circumstances which tell immensely against the admission of fluviatile conditions. Differing then, as these two series did, in their methods of formation, the overlap which we are so constantly meeting with may be assumed as unconformable overlap; or if we refuse to grant as much, we may receive it as a basis for separating the two series.

Fauna and Flora.

Search for fossils was not rewarded, even by such unsatisfactory indications of a fauna as the so called Annelide tracks: and of plants there was not the faintest resemblance to a leaf or stem on any of the shales or sandstones.

Trap.

A few intrusions of trap occur; two near Chepree, and one east of Indra.

III.—Damuda Series.

Regarding this series there are several new facts to be pointed out which will be highly interesting to those engaged in unravelling its relations to the formations usually associated with it, and the relations which its subordinate groups bear to each other.

Unconformity.

It has already been assumed that the Damúdas are unconformable to the Talchírs. Unconformity, however, also exists between the upper and middle divisions of the Damúda, and again between the Damúdas and Panchéts. The evidence to establish unconformity between the Barákar and Ránigani groups is clear and distinct, and will be fully referred to when describing the structure of the country in the neighbourhood of Hosir and Sarum.

Evidence of unconformity clear.

No break between Ironstones and Barákars.

Although a break has been discovered between these two sets of beds, nothing of the kind has been made out with respect to the Ironstones and Barákars. Conformity exists wherever the two are seen in contact, and they appear to be closely connected with one another.

The Upper Barákars are invariably transition beds, ironstones and carbonaceous shales being interstratified with coals.

Division of Ironstones and Barákars.

The division into Barákars and Ironstones is nevertheless clear upon lithological grounds, notwithstanding the existence of passage beds; and as far as observations have gone, they prove that no coal is ever found in the distinctly middle group. Coal always forms an approximate boundary line, and shows the existence of the Barákars, whether we are engaged in endeavouring to separate its beds from those of the Talchírs below, or the Ironstones above.

Fossils.

The discovery of plants has been very limited in all the groups. A few varieties appeared to indicate a more close affinity with the fossil flora of the Talcheer field

than with that of Raneegunj. No animal remains have yet turned up, although I devoted much time to the examination of rocks which I considered most likely to reward search.

Sect. 1. THE BARAKAR GROUP.—The pebbles beds of this group are well developed along the northern boundary of the field, and in some places overlap the Talchîrs and rest naturally upon the gneiss. Near the Koonar River, they are more than 40 feet thick, and extend as far west as Goomeea. A cross-fault accompanied by quartz then cuts them off, and they do not re-appear in any force until we reach Karopanee. Again, they are visible at Puchmo; but I do not think they are continuous. West of Bussutpoor they are cut out by a fault, but south of Churhee we get them again.

These conglomerates are a much more important band in this field than in the Jherria one, and thicken remarkably as they extend westwards.* Along the southern boundary there are also instances of these beds being exposed. They occur along natural and not faulted junctions.

The character of the southern boundary is very mixed, and before proceeding further with the descriptive geology of the district, I will here discuss its value as well as that of the other boundaries.

Southern boundary.—There seems especial need to introduce the partial influence of faulting in the case of the main junctions of the coal rocks and metamorphics, as there are portions of the boundaries which cannot be understood, if assumed to be natural. The highly inclined angle at which the beds may dip is not always an indication that the strata have been faulted. The southern boundary is clearly a fault north of Pichree, and retains that character as far west as Angwalee. Near this village the fault runs inside the main boundary of the field, so that the junction between the metamorphics and coal measures is

* In the Karunpoora Field, to the west of this Bokaro Field, there are some sections which expose 78 feet of these rocks.

quite natural. The conglomerates at the base of the Barákars form a slight elevation at this spot, and are seen in the river west of Angwalee. The dips of the beds are exceedingly high, being as much as 70° and 80°, but notwithstanding this fact, there is no proof of their having been shifted. This knowledge is important, and its application will be very useful in explaining some of the complications regarding the boundary further to the west.

From Angwalee to Chulkurree we find no fault excepting a cross one, which brings up metamorphics in the Damoodah. Between Chulkurree and Khetko a boundary fault occurs close to the former village; it has a few feet of Barákars to the south of it. In the neighbourhood of Khetko considerable disturbance has taken place, and the displacement of the rocks is very apparent.

From this point the fault extends to the western extremity of the field, without being thrown (as far as I could make out) by any cross ones. It skirts along the boundary, keeping inside the coal measures, as far as the Dhurdurwa River. From thence it forms the actual boundary, but south of Teelaya it once more enters sedimentary rocks, and keeps within them, until eventually it passes exclusively into metamorphics.

The occurrence of this southern fault, as I have described it, might be doubted, if only a cursory examination of the field were made. For instance, any one striking across the boundary near Khetko, and meeting the pebble beds would in all likelihood at once infer that no fault existed, the bottom beds of the Barákars being seen to rest naturally upon the gneiss. No displacement, it is true, has taken place along the outer edge of the field, and the discovery of a natural border would probably suggest a doubt as to the occurrence of any fault in the immediate neighbourhood. Nearly due north of Lalpunneea and westwards from there, no mistake can be made as to the character of the boundary. The upper beds of the Lower Panchéts are found abutting

against the metamorphics, clearly indicating a throw. Doubts, however, again arise on examining the section in the small stream west of Kodwa, as we there find real and typical Barákar sandstones near the edge of the field. Proceeding up the river, the beds which at the bottom are highly inclined continue at the same or nearly the same angle, and assume all at once the characters of the Raniganj group. These strata are conformable to those of the Barákars, and I see no other explanation which clears away difficulties so easily as a fault. The Barákars, then, at this portion of the border are represented as being south of the fault. In support of this view, the section of the Dhungurdhugwa, another small stream, to the east of Kodwa, lends great weight. The Barákars are highly inclined, but dip to the north-north-east, while the Ránigan̄js dip to the north-west. This change in the direction of dip is very marked, and such a striking contrast manifestly indicates a fault. Of course it might be due to overlap, but as we already have a fault, which is evidently full of vigour, where we last parted with it, a contrast in strike occurring in the line which would be pursued by the continuation of that fault, is most probably owing to the only cause to which we can appeal after excluding overlap.

South-east of Gosee, the extension of the fault is slightly obscure, but west of that village, the evidence is clear. The limit of the field is natural to the north of Juggaysur, being faulted only locally once or twice, and for only very short distances.

Western boundary.—The western boundary is broken, but speaking broadly, it may be called natural. All the faults which occur are ones parallel to that described above, and none are north and south displacements or approximately so, as they would be if the west border were faulted.

Northern boundary.—The north edge of the field is the mixed effect of pure denudation and faults. In the vicinity of Tapin Pindra, and

Bussutpoor, the Rániganjs are in contact with the gneiss, and Talchírs occur outside, or north of, the faulted junction. East of Bussutpoor, the boundary is natural for a short way, and the Barákars are found along the border. Close to Puchmo, the fault once more sets in, and holds steadily as far as Goomeea; beyond this village the boundary is the result of simple denudation.

Eastern boundary.—The eastern limit of the field is only faulted near Tooreeo. North of this little hamlet, the Barákars and Talchirs have not been disturbed.

Coal in Barákar group.—There is nothing peculiar in the distribution of the Barákars, which requires to be specially noted; and I shall therefore proceed to describe the coal seams of the group in the order in which they occur, commencing in the east of the field.

N. of Damoodah.—Confining details for the present to the north side of the Damoodah, the first river exhibiting coal distinctly is the Teesrah Nuddee. The seam is better seen in a small tributary; it dips at an angle of 10° to the S. S. W. The large trap dyke, marked on the map as passing east of Pichree, injures this coal.

Teesrah nuddee.

The country enclosed between the above stream and the Bhuskee Joor is broken and exceedingly jungly, and the beds are not always to be seen.

Bhuskee Joor.

A burnt seam occurs within the limits of the Mukoolee *surhud.* The dip is reversed in one place, being north-east, instead of possessing the usual southerly lie. The road from Chepree to Mukoolee crosses a river in which an inferior coal is exhibited, not exceeding two feet in thickness.

Coal near Mukoolee.

A small dyke, heading E. S. E.—W. N. W. but not traceable for more than 20 and 30 yards, occurs near the place where the reversal in dip is visible.

Dyke.

The lowest rocks in the Bhuskee Joor are to be seen a little south of the pathway leading from Karo to Chepree. The river has cut its way through the rising ground which limits the northern extension of the field. Its banks are high, and consist chiefly of the conglomerates of the Barákars interbedded with coarse grained felspathic sandstone and grits. Large blocks of rock have fallen away from the hills on either side, and intermingling with the jungle have a very pleasing effect, enhancing the general charm of the scene.

The dip of the beds is about 5° south. Passing down the river a change in strike takes place, and the dip becomes due west. The locality in which this occurs is indicated by some fields near the banks of the stream.

Coal.

The first approach to coal is observed sotuh of this spot. The bottom portion of the seam is only carbonaceous shale; and even the best part would yield very inferior fuel. A bluish, slightly calcareous, argillaceous shale caps this bed. It contains numerous plant remains, stems, leaves, and seeds, and is probably identical with a shale in the Damoodah possessing a similar composition.

Plants and seeds.

Succeeding this is a large seam whose outcrop for a part of the way is burnt. Slight faulting occurs in places. A slip of six feet is visible where a little rivulet joins the Bhuskee Joor on its left bank. The direction of the strike of the seam is not constant, and it lies somewhat round to the east. The outcrop keeps along the bank of the river, and then crosses the stream a short distance south of the most northerly road from Dhooree to Chepree.

Sandstone next appears, having a horizontal extension of 160 yards. Then coal, of which only two feet are visible above the water. The dip is 14° south-south-west. Slightly carbonaceous shales succeed. Three hundred and sixty-six yards from this point, measuring in the channel of

the stream, the Mukoolee ghât occurs. A measurable section can there be made—

			ft.	in.
1.	Sandstones	...		
2.	Argillo-carbonaceous shale with ferruginous partings ...	...	13	9
3.	*Coal* Dip 10°	...	1	2
4.	Arenaceous shale, slightly carbonaceous, a portion ferruginous	...	4	4
5.	Sandstone	...	8	6
6.	Carbonaceous shale (about)	...	2	6
7.	*Coal* seam (indistinct), Dip 12°	...	4	6
8.	Carbonceous shale with ferruginous partings (about) ...	...	14	0
9.	Sandstones	...	61	0
10.	Carbonaceous shale	...	3	6
11.	*Coal* seam (section imperfect)... ... ... Dip 22° south.	...		

Owing to the water and rushes the section is no longer clear, and no coal is exposed at the surface, until the junction of this stream with the Damoodah.

West of Dhooree (that is the portion of the village or *toleh* in which the Teekadar resides) is the Chutkurree nullah. Some seams crop out in it, but they are inclined at high angles, and of very bad quality. Nevertheless I have mapped them for purposes of reference.

The dips in this locality are very various, twisting remarkably sharply in some places. Many of the beds approach in character the Rániganjs. This resemblance is oftentimes so strong as to mislead, especially when we recollect that lithological identity of character is almost the only ground which Indian geologists have to go upon in recognising rocks for the first time. Organic remains are so rare in the Damúda series that if we depended upon palæontological evidence in order to define the boundaries of its different groups, an extravagant expenditure of time would probably take place before the typical specimen required could be found—an expenditure which the present requirements of India do not call for. So that, as a rule, the test of superposition, and when that is wanting similarity in mineralogical character, are the only two bases for classification which we can go upon. Still even in this area there are instances in which it would have been most rash to assume that a lithological resemblance justified us in correlating certain beds.

Amlo.

Flexuring accompanies the increase of dip in the neighbourhood of Amlo, and to it is due the complicated character of the stratigraphy. The strongest marked rocks are false-bedded sandstones, micaceous and felspathic, containing pebbles. The large accumulation of these pebbles on the surface is due to the length of time which the matrix from which they are derived has been undergoing denudation.

Foosro.

Near Foosro the dip is east by south, which corresponds to the west lie of the beds near Dhooree. South of Foosro the rocks are reversed at angles of 42° and 45° to north-east and east-north-east.

Foosro nuddee.

This river, which for want of a name I have called the Foosro nuddee, is formed by the confluence of two streams, one of which flows between Amlo and Karo, and the other west of the latter village.

In the Karo branch a seam occurs about 25 feet thick, dipping at a small angle, 7° west-south-east. Above it are sandstones. This is the only coal seen in the stream, and its position is between south-west and south-south-west of Karo.

A large seam injured by trap is exhibited at the junction of the two branches. The dyke is a large one, and forms near Amlo an elevation of baked argillaceous shales.

In the Amlo branch, the lowest seam occurs somewhat north of the village of Amlo; its outcrop is obscure, but the thickness appears to be four feet or so. Another seam is observable just north of the pathway between Karo and Amlo. Reddish brown slightly felspathic quartzose sandstones are then passed over, until we reach the same seam of coal occurring at the junction of the two branches of the Foosro, which was referred to above. As previously stated, it is of large size, and probably contains some good coal.

The next seam is exposed south of this; the intervening rocks are not well seen until we come to some sandstones, above which is a coal seam measuring eight feet four inches.

	Ft.	In.
Coal	2	6
Carbonaceous shale ...	0	4
Coal (inferior) ...	5	6
Total of *Coal* ...	8	0

The section from this bed is clear, and the following rocks are exposed in ascending series. Its economic worth, however, is small, and indeed it merely indicates the composition of the Barákar group to a very limited extent.

		Ft.	In.
1.	Felspathic sandstone, with a conglomerate band beneath it (thickness uncertain)		
2.	Concretionary carbo-argillaceous shales	4	0
3.	Fine grained micaceo-felspathic siliceous sandstone	0	4
4.	*Coal*	10	10
5.	Fine grained micaceous purplish and black sandstone	3	8
6.	Fine grained reddish grey sandstone	1	10
7.	Carbonaceous shale	1	0
8.	Fine grained reddish grey micaceo-siliceous sandstone, with blue slate coloured bands	5	0
9.	Concretionary carbonaceous shale	3	4
10.	*Coal* seam	1	6

	Ft.	In.
Carbonaceous shale and stony *coal* ...	0	7
Coal	0	1
Shale splintery	0	3
Coal	0	3
Total of *Coal* ...	0	11

		Ft.	In.
11.	Grey and purplish sandstones	12	0
12.	Concretionary carbonaceous shale	2	0
13.	Slightly calcareous ferrugino-micaceous sandstone	3	8
14.	Concretionary carbonaceous shale	0	3
15.	*Coal*	0	6
16.	Carbonaceous shale	3	0
17.	Red ferrugino-calcareous sandstone	0	6
18.	*Coal*. Dip S. E. 10°	0	10
19.	Carbonaceous shale	5	0
20.	Purplish micaceous sandstone	0	4
21.	*Coal*	1	4
22.	Purplish variegated shales	3	6
23.	*Coal*	0	2

The river now bends back on itself, and the rocks higher in the series are not exposed until we reach the Damoodah.

Damoodah Section. } The beds 21 to 23 are again visible; then

		Ft.	In.
24.	Arenaceous shale	0	7
25.	Sandstones	2	0
26.	Carbonaceous shales	0	9

No.	Strata	Ft.	In.	Ft.	In.
27.	Carbo-micaceous sandstones			1	0
28.	*Coal*			1	3
29.	Reddish sandstones...			1	4
30.	Concretionary carbonaceous shales, with two thin partings of sandy shale			1	8
31.	Sandstone			0	8
32.	Shale			1	0
33.	Underbed	0	2	1	2
	Coal	1	0		
34.	Concretionary carbonaceous shale			0	7
35.	Sandstone			2	0
36.	Carbonaceous shale			2	0
37.	*Coal* seam—				
	Coal	0	3	0	10
	Sandstone	0	4		
	Coal	0	3		
38.	Concretionary carbonaceous shale			0	9
39.	Yellow sandstone			1	2
40.	Carbo-argillaceous shales and slightly calcareous sandstones ...			7	0
41.	*Coal*				4
42.	Concretionary carbo-argillaceous shales and sandstones thin-bedded, and in some cases slightly calcareous			17	0
43.	Grey argillaceous shale			1	0
44.	*Coal*			9	7
45.	Concretionary carbo-argillaceous shale			3	9
46.	Thinly-bedded slightly carbonaceous sandstone			18	0
47.	Carbonaceous shale with two bands of coal...			3	4
48.	Very micaceous carbo-felspathic argillaceous shaly standstone ...			8	0
49.	Yellow slightly calcareous sandstone			2	2
50.	Reddish brown micaceous sandstone			8	2
51.	Coaly shale			1	9
52.	Concretionary carbonaceous shale			4	0
53.	Very micaceous calcareo-argillaceous sandstone and thinly-bedded shaly sandstones			5	6
54.	Concretionary carbonaceous shale			0	8
55.	Dark carbonaceous sandstone			1	3
56.	Carbonaceous shale...			0	4
57.	*Coal* (anthracitic in appearance)			0	6
58.	Micaceo-slightly calcareous sandstone			3	0
59.	Sandstones and shales alternating			2	6
60.	Underbed mingled with coal	0	8	1	9
	Coal	1	1		
61.	Concretionary carbo-argillaceous shales and sandstones ...			18	0
62.	*Coal*			0	8
63.	Carbo-argillaceous shale			0	8
64.	Sandstones and shales alternating			12	0
65.	Papery carbonaceous shale passing into coal			1	8
66.	Arenaceous and carbo-argillaceous shales			2	4
67.	Conglomerate band			0	2
68.	Fine grained micaceo-felspathic sandstone containing pebbles ...			7	0
69.	Carbo-argillaceous shales and sandy shales interstratified (about) ...			4	0
70.	*Coal* seam			5	4

	Ft.	In.	
Coal	4	6	S. E. 10°
Argillaceous shale	0	6	
Coal	0	4	

		Ft.	In.
71.	Argillaceous shale	0	6
72.	Sandstone (containing pebbles) about	6	0
73.	Thin-bedded sandstones and concretionary argillaceous shales (about)	4	0
74.	Coaly shale	0	9
75.	Sandstone (mostly slightly calcareous micaceo-ferruginous about) ...	12	0
76.	Inferior seam of coaly shale	1	1
77.	Concretionary carbo-argillaceous shale	0	5

Five feet higher in the series, there is another seam about one foot thick, possessing no dip. Faulted against the above measured beds are rocks dipping to the N. N. E. at as high an angle as 60°. They belong to the upper portion of the Barákar group, and consist of sandstones and shales. The sandstones have a prevailing yellow tint. The shales are greenish grey argillaceous beds, concretionary as a general rule, but there are others sandy in composition and fine in texture, which usually display a great variety in colours, white-grey, dark-grey, yellow, and occasionally light purple. Flexuring is equally well seen in these beds, as in those near Dhooree and Amlo, and further down the Damoodah dips to the east and south and to intermediate points occur. The map very clearly exhibits all that calls for attention in this part of the field.

The dyke marked at the mouth of the Foosro Nuddee injures a seam of coal which crops out along the southern bank of the Damoodah, becomes obscured, and then reappears close to the Godo Nullah. The dips of the rocks in the neighbourhood of Foosro and Korgullee are very much less than those to which we have just been referring, from 5° to 10° are the ordinary amounts.

Korgullee River.

The boundary of the field is well exposed in this stream. The Talchírs at the base are about 20 feet thick, and succeeding them are Damúda grits and conglomerates. The full effect of a torrent when swollen by the annual rains may be seen and studied here; masses of rock of every size and shape strew the bed of the river so thickly that it is a matter of considerable bodily toil to clamber over them.

An outlier of Barákars caps the hill west of the stream. The first approach to coal is made by a bed of coaly shale about eleven inches thick, with an under-bed of one inch. Above it are conglomerates. Continuing down the Nuddee no seams are seen for some way. The dip becomes 8° south, and then we have—

Coal.

		Ft.	In.
1.	*Coal* seam (mixed and poor in quality)	35	0
2.	Felspathic carbonaceous sandstone	24	0
3.	*Coal* and carbonaceous shale	80	0
	Dip 7°		
	These measurements are very rough, and the seams are so obscure that the thicknesses of the partings cannot be given.		
4.	Grey argillaceous shale	11	0
	(Road to Budkaro.)		
	For some way only sandstones are partially seen, and then comes another seam—		
5.	Coal seam, (it has been on fire).		
6.	Brownish concretionary shales a few feet.		
	Dip 6°		
7.	A series of carbo-micaceous shales, fine grained carbo-arenaceous sandstones and carbonaceous shales	85	0

For 400 yards loose sand and clay obscure the section, then a few rocks are seen. Again the beds become hid, until we arrive at the first bend of the river north of the village. A dotted line in the map has been put to indicate a probable seam which occurs north of this first bend. Some pieces of coal were turned up by a plough in the fields west of the spot which I have shown; and as their quality was somewhat superior to the other coals in the neighbourhood, I judged it best to mark the place. A burnt ridge heads directly for the locality, so that in all likelihood a seam does exist as I have suggested.

South of the village a seam of very large size occurs, dipping at an angle of 5° and 6°. Its least computed thickness is 98 feet. Of course a large portion of it is shale, but still there is a considerable amount of coal in it.

These large seams are very characteristic of the lower horizon of the Barákars, and are generally not met with higher in the group.

This is the largest tributary of the Damoodah yet met with, and it extends far up into the metamorphic country north of the field. The lower Barákars are, as usual, admirably seen, resting upon a thin band of Talchírs. The river where it enters the field passes through precipitous hills, the base of which are gneiss and the upper portion coal measures.

Godo River.

A tributary joins the Godo on its left bank, about a mile and a half north of Berembo. Between this point and the boundary the Godo exposes five seams, but not one of them contains good coal. The largest seam is the one a little north of the junction of the tributary. It has been on fire, and its outcrop produces a high hill on both sides of the river. No coal occurs until within a quarter of a mile of Berembo, when we get a seam; the upper and lower portions appear to be the best, the middle part being stony. It is impregnated by iron, as are indeed most of the seams here. It has a total thickness of 30 feet, and dips at an angle of 7°. Above come—

Coal near Berembo.

		Ft.	In.
1.	Stony carbonaceous shale	1	0
2.	Micaceo-felspathic siliceous sandstone	42	0
3.	Sandstone and shale—the former thin-bedded	60	0
4.	*Coal* seam	11	0
	Then 67 yards are concealed—		
5.	*Coal* seam		
	For 433 yards the rocks are covered by water; calculated thickness...	130	0
6.	Micaceo-felspathic siliceous sandstone	8	0
7.	Dark carbo-siliceous shales	6	6
8.	*Coal*	0	8
9.	Concretionary carbo-siliceous shales which become quite horizontal, and then dip slightly to the north. The coal eight inches thick, reappears, and so do the shales under it.		

The measurements on the south side of the synclinal are—

	Ft.	In.	
No. 9.	16	0	
„ 8.	0	8	
„ 7.	4	0	(not 6 6)
„ 6.	4	0	(not 8 0)

On the north side of the synclinal it is hid by water; here it is at top—

	Ft.	In.
Slaty carbonaceous shale	1	6
Coal seam, partly seen	9	8
Crushed part	1	8
Good *Coal*	8	0

The dip reverts to the south, and No. 8 is again visible, and the full thickness of No. 9 is exposed, namely, 36 feet. (In the first place where seen, some of the rock is denuded.) Then a small slip takes place, and south of that come—

10.	Thin-bedded micaceo-silicous sandstone and carbonaceous shales, dip 10° ...				70 0
11.	*Coal* seam ...				88 0
		Ft. In.			
	Stony coal	13 0	Dip 5°		
	Dyke east and west.				
	Coal mixed	75 0			

This is one of the largest seams occurring in the field, and is continuous with the one south of the village of Korgullee. The quality of the coal in this section is better than in the former ones; and it is occasionally, though not often, used by the villagers.

This portion of the field, now for the first time described, is the richest in the Bokaro area, and would be well worth the trouble of opening up. The roads, it is true, are not very good, but one could easily be made, which, after crossing the hills to the north of the field, would emerge on the plain that slopes gradually from Hazareebagh to Raneegunj. The quality of the coal is in many instances good, and, I believe, would be found still better, if more opportunity existed for testing it. It would be scarcely fair to consider the top-weathered coals average specimens, as such cannot be the case owing to the concentration of inorganic matter, and the deposition of extraneous impurities from water.

West of the Godo the geological structure of the country is not well seen. The dip along the northern boundary is pretty steady both in amount and direction, varying from 7° to 10° and from south-east to south by east.

Near Gobinpoor a cross fault shifts the northern boundary. The evidence of a displacement is complete, and excellent confirmation is afforded by a line of springs breaking out at the junction of the gneiss and Barákars. Our attention ought always to be directed to the discovery of springs, and suspicions raised as soon as they are met with, as they often indicate a break in the rocks.

Two more instances will be subsequently pointed out in the present field, in which the existence of springs has confirmed the inference previously arrived at that a fault occurred. In one case there was some obscurity and doubt as to whether the view which I had taken was correct, which the discovery of a spring helped to dispel.

The heading of the Gobinpoor cross fault is 25° west of north. It is probably continued across the Koonar and instrumental in cutting off the rocks west of Khetko. This is by no means clear, however, and so it is indicated by a dotted line only. A diversity of dips is visible in the Koonar north of Buriya, which is suggestive of a fault.

Cross fault.

The village of Gobinpoor consists of three tolehs. Two dykes occur near the middle one, striking a little north of west.

A good section is seen in the Montiko Nuddee. The first seam of coal is exposed 500 yards south of the boundary.

Dip 20°

		Ft.	In.
1.	*Coal* seam	24	0
2.	Carbo-argillaceous and carbo-siliceous shales	41	0
3.	*Coal* (inferior)	0	5
4.	Sandstones, fine grained and slightly carbonaceous	34	0
5.	Beds hid for 133 yards—(calculated thickness)	136	0
6.	Seam injured by trap.		
7.	Beds partially hid	102	0
	The dip changes from SE. to nearly S.		
8.	Seam injured by trap.		
	Beds for the most part obscured for 1,100 feet across their strike.		
9.	Shales with ironstones	7	0
10.	Yellow sandstone	5	0
11.	Carbo-argillaceous shales	10	0
12.	Sandstone	4	0
13.	Coaly shale	1	0
14.	Ironstone	0	2
15.	Shales	5	0
16.	Ferrugino-calcareous sandstone...	0	5
17.	Carbo-argillaceous shales	4	0
18.	Sandstone	4	0
19.	Shales	12	0
20.	Felspathic sandstone	4	0
21.	*Coal*	2	4
22	Beds partially visible—(calculated thickness)	37	0
23.	*Coal* seam (dip 22°)	8	0
24.	Reddish grey, thin-bedded micaceous sandstone with concretionary carbonaceous shales	87	0
25.	*Coal*	4	2

		Ft.	In.
26.	Carbonaceous shale and reddish yellow micaceous siliceous sandstone	7	6
27.	*Coal*	1	4
28.	Concretionary carbonaceous shale	6	8
29.	Purplish micaceous shale	2	0
30.	Concretionary carbonaceous shale, portions containing ironstone ...	4	0
31.	Slightly carbo-arenaceous shales, with micaceous siliceous sandstones thin-bedded	13	0
32.	*Coal*	0	7
33.	Concretionary carbonaceous shales	10	0
34.	*Coal*	1	2
	Dyke running E. N. E.		
35.	Grey micaceo-arenaceous sandstone	15	0
36.	Shaly *Coal*	1	6
	One hundred and thirty yards from this the highest bed of coal in the river, comes the Koonar.		

None of the coal exposed in this section is very valuable, and indeed if the quality were good, it occurs generally in bands of too small thickness to render it useful. The first seam which was mentioned No. 1, measuring 24 feet, is nearly all carbonaceous shale, and it was with difficulty that I succeeded in igniting some pieces which I had collected in order to make a fire.

The conglomerates are well developed in the tract between the Montiko and Koonar, and in the latter river, there is a fine exhibition of them.

In the hilly country east of Gobinpoor, patches of Barákars are as common as outliers of Talchírs, and the loose pebbles and pebble beds of the former are often unexpectedly met with, whilst traversing the jungle.

The difficulty experienced in mapping the small outliers of Talchírs is equally felt with regard to these spreads of Barákars, but I have indicated them as well as I can.

Koonar River.—The Koonar affords an excessively poor section for the first mile and a half of its course through the sedimentary rocks. An indistinct outcrop of coal is occasionally observable, but the whole section is imperfect. South of the mouth of the Montiko some shales and sandstones appear, but it is not until we arrive east of the Gobinpoor fault that coal is visible. The first seam measures 31 feet, but this amount may be too much, as its outcrop is not very clear.

In the reach due east of Buriya, there are three good seams which dip at moderate angles, 10° or 12°. The fourth seam marked in the map does not contain much coal.

The following is a carefully measured section :—

			Ft.	In.
1.	Carbonaceous shale			
2.	*Coal* seam		25	0

	Ft.	In.
Coal	1	0
Carbonaceous shale, concretionary	2	0
Coal	2	0
Carbonaceous shale	0	6
Coal (inferior)	10	6
Carbonaceous shale	0	9
Coal	5	0
Concretionary shale	0	8
Coal	1	3
Stony carbonaceous shale ...	0	3
Coal	1	3
Total of *Coal* ...	21	6

			Ft.	In.
3.	Fine siliceous sandstones, brownish-red in colour, with one bed of carbonaceous shale		63	0
4.	*Coal* seam		5	5

	Ft.	In.
Coal	0	5
Micaceo-siliceous carbonaceous shale	0	5
Coal	0	2
Siliceo-carbonaceous shale ...	0	4
Coal	1	1
Siliceo-carbonaceous shale ...	0	10
Coal	1	0
Siliceo-carbonaceous shale ...	0	10
Coal	0	4
Total of *Coal* ...	3	0

		Ft.	In.
5.	Siliceo-carbonaceous shale	3	4
6.	*Coal*	0	9
7.	Carbonaceous and coaly shale	2	10
8.	*Coal* seam (mixed)	19	0

Dip 10°.

		Ft.	In.
9.	Grey micaceo-felspathic sandstone containing carbon ...	27	0
10.	Purple and dark carbo-siliceous shales	29	0
11.	*Coal* seam	7	4

	Ft.	In.
Coal	0	10
Carbonaceous shale	1	6
Coal	5	0
Total of *Coal* ...	5	10

Dip 20° E. S. E.

		Ft.	In.
12.	Fine siliceous shales and sandstones, and greenish grey argillaceous shales with ironstone	34	0

The section is then hid by sand.

A large dyke crosses the river as represented on the map. It is traceable south of the Koonar, but is not visible in the Damoodah, which is somewhat extraordinary, as it is by no means a small one.

Opposite the villages of Jereedeeh and Jerungdeeh coal is again seen, but dipping west. It is nearly destroyed by permeation of trap throughout it. From this seam some fine specimens, illustrating the occurrence of the trap, were obtained. The plan resembles a series of irregular quadrangles. These are produced by injections of trappean matter, which filled up numberless cracks of shrinkage more or less at right angles to each other. These cracks occurred along the structural lines so common in coal, hence their regularity; for if they were due merely to the forcible passage of trap through the mass of heated coal, they would present a much more unsystematic pattern than they do.

Coal near Jereedeeh.

A seam on the south bank of the Damoodah, through which the Foosro dyke passes, affords some very good samples of trap-affected coal. The quadrangular structure is rendered very prominent by the contrast in colour of the black carbon and light yellowish grey of the weathered trap; and from the superior hardness of the latter, it generally projects above the surface of the coal.

At the mouth of the Koonar there is a sharp anticlinal.

Coal South-East of Jereedeeh.—A seam is seen south-east of Jereedeeh in the fields bordering upon the Damoodah.

The dip near the southern boundary becomes reversed, and it is evident that as hitherto we have had a regular succession of strata dipping southwards whose thickness far exceeds that of the reversed beds, there must be a fault in the neighbourhood; whether forming the limit of the field or not depends upon the extent of denudation which the country has suffered posterior to its formation.

Reverse Dip.

Before describing the area west of the Koonar, it will be better to give the sections of the Damoodah, as that river does not expose any of the coal measures west of the village of Khetko.

Damoodah.—The lowest bed in the Damoodah is seen in the bend of the stream due north of Pichree, and the section in ascending series is—

		Ft.	In.
1.	Brown sandstones and grit		
2.	*Coal* (good)	2	0
3.	Flaggy sandstone	4	0
4.	*Coal* seam	1	7

	Ft.	In.	
Coal	0	3	This is faulted in one place.
Carbonaceous shale	0	4	
Coal	0	2	
Carbonaceous shale	0	5	
Coal	0	5	
Total of *Coal* ...	0	10	

		Ft.	In.
5.	Sandstone	5	0
6.	*Coal* seam	166	0

	Ft.	In.
Coal and shale	30	0
Dyke, small.		
Slaty carbonaceous shale and coal mixed; the former predominating to a great extent	136	0
Coal	0	6

		Ft.	In.
7.	Micaceous sandstone containing pebbles; it possesses a ferruginous weathered surface	30	0
8.	*Coal* seam	68	0
	This is better seen on the right than on the left bank of the river.		
9.	Micaceous felspathic siliceous sandstones	61	0
10.	Sandy-carbonaceous shales	17	0
11.	*Coal* seam	37	4

	Ft.	In.	
Coal (about)	0	6	Dip 20° S. S. W.
Carbonaceous shale	1	0	
Coal	1	0	
Carbonaceous shale	4	4	
Coal (poor)	30	6	

This seam occurs 130 yards east of the mouth of the Bhuskee Jooreea. Its dip is higher on the right side of the river than on the left.

Some additional seams are exposed, but they are inclined at angles which render them quite useless. Even those given in the section dip too high. The enormous bed No. 6 is of very poor quality; it is cut through by the Pichree dyke.

The subjoined section is given merely for the purposes of identification; the coal seams mentioned in it are totally unserviceable:—

		Ft.	In.
1.	Six hundred yards west of the out fall of the Bhuskee Joor a small bed of coal is exposed.		
2.	Intermediate beds, dipping at 60° N. N. E.	129	0
3.	*Coal*	2	4
4.	Argillo-siliceous shales	14	6
5.	*Coal*	2	0
6.	Greenish concretionary argillo-siliceous shales, with greenish argillaceous sandstones	188	0
7.	*Coal*	0	4
8.	Concretionary, greenish, slightly ferruginous argillaceous shales ...	80	0
9.	*Coal*	3	6
10.	Same as No. 8	70	0
11.	*Coal*	3	0

Dip 85°

The beds are in this place nearly vertical. The character of these strata is somewhat different from ordinary Barákars, and approaches that of the Ràniganj group. There are, however, no ironstone shales to indicate that the horizon of these rocks is higher than that of the Barákars.

Eastern side of loop.—In the eastern side of the loop of the river the section is necessarily different from that of the western. The beds are more denuded, which have felt only the slight disturbing influence of the eastern fault.

The line of quartz breccia passing between the two tolehs of Tooree is very well marked. The throw of the fault along which it occurs is slight.

The remaining sections of the Damoodah have been made in the vicinities of the two villages of Angwalee and Chulkurree. They are very partial, and expose coal dipping at extremely high angles.

Commencing a few yards east of the Kanjo Nuddee, and then proceeding westwards, we find—

		Ft.	In.
1.	Grey micaceo-siliceous sandstones		
2.	Concretionary carbo-arenaceous shales containing irregular bands of impure ironstone, and thin-bedded fine grained reddish brown ferrugino-micaceous sandstones		
3.	*Coal* seam. Dip 65° ... ... (This is again seen on the west of the Kanjo Nuddee).	3	8

Here we come to the mouth of the Kanjo. The section continued in it, in descending order, is—

		Ft.	In.
4.	Thin-bedded reddish brown siliceo-micaceous sandstones, and carbo-argillaceous shales	43	0
	Dip N. N. W. by N. 60°.		
5.	*Coal*	6	0
6.	Carbo-argillaceous shales	25	8
7.	*Coal* seam	15	6
	A few yards south of this comes the boundary.		

Returning once more to the Damoodah—

		Ft.	In.
	No. 3 reappears, then higher in the series:—		
a & b.	Nos. 2 and 1. Thin-bedded micaceo-siliceous sandstones ...	20	0
b.	*Coal* seam.	29	0

	Ft.	In.
Coal (good)	13	0
Coal containing irregular partings of ironstone and shale ...	16	0

c. Carbonaceous shales with black band, and thin bedded micaceous shales and sandstones succeeded by sandstones containing pebbles.

The section is then obscure to within a short distance of a nullah, between the Kanjo and Jhoonjko nuddees, where a seam occurs dipping at an angle of 50° and possessing a thickness of 38 feet.

The next rocks above this coal are not exposed in the Damoodah, and no intelligible section is seen until opposite the mouth of the Hurriladeeh Nullah.

A little west of the Jhoonjko stream, a cross fault cuts off the Barákars, and brings them against metamorphic rocks in the bed of the Damoodah. In the Jhoonjko Nuddee no strata occur near its out-fall, but on going up it, the seam *b* of the above section shows in the bank of the river, and also No. 3. The boundary exposed in the Jhoonjko is a natural one, and pebble beds are seen resting upon the gneiss.

The throw of the south fault near Angwalee is not great. This can easily be shown to be true, because, in the Jhoonjko, there is an unbroken succession from the conglomerate to the two seams which are visible in the Damoodah, so that the fault cannot exceed the thickness of strata included between them. Some indistinct outcrops occur west of Angwalee.

Going up from the Damoodah, the first seam of coal dips at about 25° north by east, and is approximately 30 feet thick. This is separated from another underneath it, by carbonaceous shale and sandstone four feet six inches thick. The second seam is 45 feet thick, and dips at a higher angle than the first, namely, 30°. Under this the rocks are conglomerates, and coarse grained felspathic siliceous sandstones.

Hurriladeeh Nuddee.

East of Chulkurree the Damoodah section has been already given. West of the mouth of the Foosro Nuddee there are a few seams to notice; one four feet thick dipping to the south-south-east. This is lower in the series than No. 1 of the Foosro section. Below the four feet seam are two other small ones. Close to the mouth of the Godo, the Foosro dyke and another occur.

The dips in the western side of the loop north of Chulkurree vary a good deal, and the beds are cut out by a fault. The area around Chulkurree is not very clear, being covered by a great deal of alluvium. There appears to be no displacement along the boundary east of the village.

Near Khetko the Damoodah no longer flows through the field; there is a good deal of faulty country about there. The boundary passes through the village of Khetko; the strike of the beds being west by north, and the dip 50°.

The breadth of the field becomes very contracted near the junction of the Koonar with the Damoodah, but on the meridian of Goomeea it swells out to a breadth of four miles and a half. The Barákars are well developed around Hazaree, but very few outcrops of coal are exposed.

Near Jerungdeeh there are two streams, in the most easterly of which four seams are exhibited; the one highest in the series is the largest and has a thickness of four feet. Its dip is 15°. At the mouth of the most westerly

Coal near Jerungdeeh.

nullah gneiss occurs. Further up the stream pebble beds are visible, forming a natural junction, although they are highly inclined. Somewhat north of this a change in dip is observable, and a coal seam that occurs is very much crushed. A fault line probably exists, which, I am of opinion, is the continuation of the one south of Loogoo Hill. The similarity of phenomena in this nullah and the Dhungadhugwa Nuddee is a noteworthy circumstance, namely, a sharp change in the direction of dip.

North-east of Sobang a tributary of the Koonar exposes five seams. The largest is 16 feet, and it occurs highest in the series.

Coal north-east of Sobang.

Coal near Banddeeh.

Nearly north of Banddeeh, in the Bokaro Nuddee, a small seam occurs, dipping at a high angle.

Very little coal is exposed between Goomeea and Loogoo Hill, and none of any value. A very thin bed crops out in a nullah east of Ooda. An imperfect section of the Barákars is seen in the Bokaro west of Koyeeotand.

		Ft.	In.	
1.	The first seam under the Ironstones is	4	6	thick. Dip 44°
2.	Sandstones and shales ...	150	0	
3.	*Coal* with trap			
4.	Siliceous sandstones, (about) ...	60	0	

Then boundary, which runs in the bed of the stream. The junction is beautifully exposed all the way to Lalgurh. North by east of this village, the line passes 20 yards inland of the left bank of the river.

Opposite Lalgurh the following section is seen in ascending order:—

		Ft.	In.
1.	Carbonaceous shale. Dip 23°	4	6
2.	*Coal*	4	6
3.	Carbonaceous shale	3	9
4.	Grey carbonaceous shale	3	6
5.	Ordinary felspathic siliceous sandstone	27	0
6.	Sand for 50 yards		
7.	Grey felspathic siliceous sandstones, fine grained, some of them are slightly impregnated by iron. Dip 13°	25	0
8.	Purplish micaceous shales and ordinary felspathic siliceous sandstones	11	0
9.	Grey argillaceous shales	3	0
10.	Ferruginous shale	1	0
11.	Carbo-argillaceous shale	2	0

12.	*Coal*	1	0
13.	Micaceous arenaceous shale	0	6
14.	Carbo-argillaceous shale	1	3
15.	Slightly felspathic siliceous sandstone	2	0
16.	Carbonaceous shale with parting of sandstone	1	3
17.	Sand in river		
18.	Very fine grained variegated micaceous siliceous sandstone exhibiting false lamination	9	0
19.	Carbonaceous shale containing ironstone	2	0
20.	Sandstone	4	10
21.	Concretionary carbonaceous shale	4	6
22.	Sandstone and very finely laminated micaceo-arenaceous shale ...	7	0

A portion of the beds are afterwards seen that compose No. 17, and the section is—

17*a*.	Carbonaceous shale having a splintery fracture ...	3	0
17*b*.	Variegated micaceo-siliceous thin-bedded sandstones ...	4	0
17*c*.	Yellow calcareous sandstone	0	6
17*d*.	Thin-bedded sandstones and shales	8	0

After sandstones No. 22, the next strata are all lower in the section. A very interesting little piece of geology occurs north of Karopanee, a quartz breccia runs north of the village, and probably indicates the continuation of the fault, which forms the boundary of the field south of Burhoo. A small fault heading north-north-west cuts off the patch of Barákars and Talchírs which is seen north of Karopanee.

Coal near Karopanee.—East of Karopanee there are two seams which dip at an angle of 28° south-south-east.

A clear section is that of the little stream east of Dhunneeya. A seam occurs a short way north of the Bokaro, and at the same spot a dyke is seen running east and west.

Dhunneeya Nuddee.

Fifty yards north of this seam (the intermediate beds are sandstones) we get another seam much impregnated by iron. The section is—

	Ft. In.	
Carbonaceous shale ...	2 3 to 3 0	Dip. 12° to 14°
Coal	3 0	
Carbonaceous shale ...	...	

Twenty yards further north—

	Ft.	In.		
Coal	4	4		Dip. 14°
Grey argillaceous shale ...	1	4		
Coal	1	6	(seen)	
The lower portion hid, appears to be	8	10		

The river then divides, and passing up the right branch we get—

		Ft.	In.
1.	Felspathic siliceous grit ... ... about	30 to 40	0
2.	Argillaceous shales	6	0
3.	*Coal*	0	2
4.	Argillaceous siliceous shales	0	3
5.	*Coal*	0	1
6.	Carbo-argillaceous shales	1	4
7.	*Coal*	0	6
8.	Argillaceous shale	0	2
9.	*Coal*	0	3
10.	Reddish brown shale (containing vegetable remains)	2	0
11.	*Coal* with partings	1	0
12.	Argillo-siliceous shale	0	8

A little north of this we have the boundary very slightly faulted. The bottom rocks are sandstones containing many pebbles and boulders.

The dyke is again seen in the nullah passing west of Dhunneeya. The inclination of the beds in the river is very high, 50° to 62°. Only one seam of coal is visible in it.

Bhagalatta Nuddee.

One of the very best sections of the Barákars in the whole field is met with in the Bhagalatta; there appears to be no break in the succession of the beds exposed between the synclinal, which will be referred to in the Chootooa section, and the north boundary of the field, so that I am justified in mapping the country as Barákars. There is a resemblance, however, in the rocks of the Chootooa to those of the Raníguŋj group, but if no break can be shown between them and those in the Bhagalatta (which are unquestionably Barákars), the similarity must be granted to be accidental only.

The section of the Bhagalatta in descending order is as follows; the first bed mentioned occurs 270 yards north of the Chootooa:

		Ft.	In.
1.	Felspathic siliceous sandstone. Dip 25° S.	42	0
2.	*Coal*	1	7
3.	Concretionary argillaceous and carbonaceous shales	15	0

		Ft.	In.
4.	Sandstone	0	10
5.	Carbonaceous shale	0	9
6.	*Coal*	1	0
7.	Arenaceous shale	1	2
8.	Coaly shale	0	8
9.	Carbonaceous shale	0	10
10.	Mainly composed of slightly ferruginous sandstones, with some bands of carbo-argillaceous shales	35	6
11.	Concretionary carbonaceous shales, with a band of limestone ...	2	0
12.	Slaty carbonaceous shale	10	0
13.	Coaly shale	0	3
14.	Slightly carbonaceous micaceo-arenaceous shale	27	0
	Dip 20° S. S E.		
15.	Coaly shale	0	7
16.	*Coal* seam	6	1

	Ft.	In.	
Coal	1	7	Dip 20°
Slaty carbonaceous shale ...	1	6	
Coal	3	0	
Total of *Coal* ...	4	7	

		Ft.	In.
17.	Slightly carbonaceous sandstone;	3	6
	A dyke running with the strike.		
18.	Strong carbonaceous shale	3	7
	Dip 15°. The angle of dip decreases suddenly		
19.	*Coal* and coaly shale, the latter predominating	9	6
20.	Dark micaceo-argillaceous sandstone	3	6
21.	Coaly shale	0	4
22.	Like No. 20. Plant impressions	10	0
23.	Micaceous sandstone containing pebbles. Dip 25°	32	6
24.	Reddish brown felspathic siliceous sandstones containing pebbles ...	42	0
	The river cuts a small gorge through this sandstone. The section further up is admirably exposed; a large seam of coal occurs.		
25.	*Coal* seam. The upper 2 feet good	13	0
26.	Sandstone, white siliceous, and containing a small quantity of Carbonate of Lime	15	0
	This passes into characteristic Damúda grit.		
27.	*Coal* (good). Dip 25°	16	8
28.	Carbo-argillaceous sandstone. Dip 30°	5	0
29.	Sharp grained felspathic siliceous sandstones impregnated with iron	22	0
30.	Variegated fine grained micaceous sandstone	7	0
31.	*Coal* (inferior)	3	6
32.	Thin-bedded sandstone	4	4
33.	Carbonaceous shale	2	0
34.	*Coal* (good) ... ... 6 ft. 0 in.; ,, (stony) ... ... 2 ft. 0 in.	8	0
35.	Carbo-siliceous sandstone	3	0
36.	Siliceo-felspathic sandstone	10	0
37.	Blue carbonaceous shale containing ironstone; varies from 0 8 to ...	1	3
38.	*Coal* of superior quality	1	8
	Underbed	0	4
39.	Carbonaceous sandstone. Dip 25°	2	0
40.	*Coal* (inferior)		
41.	Slaty carbonaceous shale		
42.	Sandstone highly felspathic and siliceous, with stains of *Coal* and containing numerous quartz pebbles		

43. A thin bed of *Coal* and carbonaceous shale very imperfectly seen.
44. Compact quartzose sandstones, 70 yards horizontal.

This sandstone is not well seen, and indeed, after No. 42, the section is very imperfectly exposed.

The boundary is not more than 300 yards north of the last-mentioned sandstone.

The next section occurs in the river close to Puchmo, which joins the Bhagalatta before that stream unites with the Chootooa.

The lowest strata are, as in the Bhagalatta, pebble beds. The section is by no means perfect, and the immense amount of jungle surrounding prevents the possibility of determining the exact position of a seam or other bed, which one might feel anxious to do. Two outcrops of coal occur *north* of the road from Puchmo to Monda. *South* of the road coarse sandstones show, and then another seam of coal measuring eight feet. This crops out along the banks of the nullah which courses here parallel to the strike of the seam. A change in direction of dip is observable from that which holds near Dhunneeya, and in the Bhagalatta, being south-west or south-south-west.

Higher in the series than the eight feet seam, is a bed of coal one foot two inches thick. Sixteen feet above this there is a three feet seam.

South of this nothing shows in the stream excepting some pieces of trap whose source is hid. Near the mouth of the river the strata are inclined at high angles, and four seams occur, which are also exposed in the Chootooa.

The following is the section in descending order, as the river flows northwards :—

		Ft.	In.
1.	Coaly shale. Dip 60° S. W.	4	3
2.	Ribboned black and white sandstone	8	6
3.	Carbonaceous shale	0	8
4.	*Coal*	2	10
5.	Fine grained micaceous slightly felspathic siliceous sandstone, thick-bedded	43	0
6.	Variegated black and white sandstone	10	0
7.	Coaly shale	1	6
8.	Arenaceous and carbonaceous shale	38	0
9.	Sandstone, highly micaceous and felspathic	40	0
10.	*Coal* (good) S. S. W. 70°	2	0

		Ft.	In.
11.	Thick-bedded sandstone	29	0
12.	*Coal*	1	0
13.	Variegated sandstones	13	8
14.	Calcareous sandstone	1	3
15.	Thin and-thick bedded sandstones	72	0
16.	Coaly shale. Dip 68°	3	6
17.	Concretionary argillaceous shale	1	3
18.	Carbonaceous shale	2	8
19.	Micaceo-argillaceous shale	3	5
20.	*Coal*	3	6

Eighty-three yards from this is the mouth of the Bhagalatta.

In the ground between this stream and the Chootooa there is a deposit of kunkur. It has been quarried in order to supply lime for the bungalows building on Jilunga Hill.

The sections west of Puchmo are few and imperfect. Numerous small streams occur, but their channels are invariably filled by sand. A few rocks are seen in the Jhirna Nullah at the boundary.

In ascending order—

		Ft.	In.
(a).	Fault rock.		
1.	Greenish slightly felspathic and micaceo-siliceous sandstone. Dip 60° S. S. E.	39	6
2.	Slightly carbonaceous shale. Dip 50°	15	3
3.	Argillaceous shale slightly concretionary	1	9
4.	Slightly carbonaceous argillaceous shale	0	8
5.	Greenish micaceo-argillaceous shale	3	9
6.	Carbonaceous shale	0	11
7.	Highly felspathic siliceous sandstone, greenish and thick-bedded, containing also boulders	6	9
8.	Greenish, yellow, micaceo-argillaceous shale	1	6
9.	Like No. 7	4	3
10.	Micaceo-argillaceous shales, concretionary in places, with a yellowish green colour	20	0

A few feet of sandstone; and then the rocks are hidden by sand up to the union of this stream with the Chootooa.

Another stream, the Sut Nuddee, to the west of this, again exposes Barákars near the boundary. A seam of coal occurs in it, a portion of which is thrown up by two parallel faults, heading north-south.

Above the coal comes sandstone, which is also faulted; the direction of this last fault is north-north-west, and its throw is perhaps 40 feet. A difference in the direction of dip is seen on either side of the fault. West of it the beds dip south; east of it they dip south-south-east. South of

Bussutpoor, a fault occurs between the Barákars and Ironstones. This is one of the instances in which the existence of springs confirmed the decision which I had already formed as to the presence of a fault. Regarding this fault there can be no doubt, and the only regret I have to express is that others in the vicinity are not so clear. The fault was first suggested by finding that the middle and lower groups were brought into contact with each other, the former possessing a dip of 25° to the north by east, whilst the latter dipped to the south at an angle of 35°. No anticlinal or synclinal could explain such a relation, and there was no help for it, but to bring in a fault. As confirmation, the discovery of the springs was most fortunate.

Chootooa section.

No coal is seen in the actual bed of the river, until half a mile or so west of the Sut Nuddee. The dip of this seam is 9° north-west. It is a little over a foot in thickness. The real section of the Chootooa commences first at the bend of the river, where it is joined by the stream coming from Kheddala. The measurements were chiefly made of the beds east of the powerful dyke which crosses the stream nearly due south of Rayhaon. A bed of good coal six and a half inches thick occurs along the right bank dipping north-north-east 13°. It has above it stony coal one foot seven and half inches. Below it come—

	Ft.	In.
Slaty carbonaceous shale	3	0
Good *Coal*	0	4
Slaty carbonaceous shale	0	5
Coal about one foot and six inches. It merges into carbonaceous shale along its strike	1	6
Coal	0	3

The same beds are re-exposed further down the stream, at the place where it flows north-east. The section is—

	Ft.	In.
Stony *Coal* above	1	0
Good *Coal*	0	6
Slaty carbonaceous shale	5	0
Coal	0	4
Slaty carbonaceous shale	0	5

		Ft.	In.
11.	Thick-bedded sandstone	29	0
12.	*Coal*	1	0
13.	Variegated sandstones	13	8
14.	Calcareous sandstone	1	3
15.	Thin and-thick bedded sandstones	72	0
16.	Coaly shale. Dip 68°	3	6
17.	Concretionary argillaceous shale	1	3
18.	Carbonaceous shale	2	8
19.	Micaceo-argillaceous shale	3	5
20.	*Coal*	3	6

Eighty-three yards from this is the mouth of the Bhagalatta.

In the ground between this stream and the Chootooa there is a deposit of kunkur. It has been quarried in order to supply lime for the bungalows building on Jilunga Hill.

The sections west of Puchmo are few and imperfect. Numerous small streams occur, but their channels are invariably filled by sand. A few rocks are seen in the Jhirna Nullah at the boundary.

In ascending order—

		Ft.	In.
(a).	Fault rock.		
1.	Greenish slightly felspathic and micaceo-siliceous sandstone. Dip 60° S. S. E.	39	6
2.	Slightly carbonaceous shale. Dip 50°	15	3
3.	Argillaceous shale slightly concretionary	1	9
4.	Slightly carbonaceous argillaceous shale	0	8
5.	Greenish micaceo-argillaceous shale	3	9
6.	Carbonaceous shale	0	11
7.	Highly felspathic siliceous sandstone, greenish and thick-bedded, containing also boulders	6	9
8.	Greenish, yellow, micaceo-argillaceous shale	1	6
9.	Like No. 7	4	3
10.	Micaceo-argillaceous shales, concretionary in places, with a yellowish green colour	20	0

A few feet of sandstone; and then the rocks are hidden by sand up to the union of this stream with the Chootooa.

Another stream, the Sut Nuddee, to the west of this, again exposes Barákars near the boundary. A seam of coal occurs in it, a portion of which is thrown up by two parallel faults, heading north-south.

Above the coal comes sandstone, which is also faulted; the direction of this last fault is north-north-west, and its throw is perhaps 40 feet. A difference in the direction of dip is seen on either side of the fault. West of it the beds dip south; east of it they dip south-south-east. South of

Bussutpoor, a fault occurs between the Barákars and Ironstones. This is one of the instances in which the existence of springs confirmed the decision which I had already formed as to the presence of a fault. Regarding this fault there can be no doubt, and the only regret I have to express is that others in the vicinity are not so clear. The fault was first suggested by finding that the middle and lower groups were brought into contact with each other, the former possessing a dip of 25° to the north by east, whilst the latter dipped to the south at an angle of 35°. No anticlinal or synclinal could explain such a relation, and there was no help for it, but to bring in a fault. As confirmation, the discovery of the springs was most fortunate.

Chootooa section.

No coal is seen in the actual bed of the river, until half a mile or so west of the Sut Nuddee. The dip of this seam is 9° north-west. It is a little over a foot in thickness. The real section of the Chootooa commences first at the bend of the river, where it is joined by the stream coming from Kheddala. The measurements were chiefly made of the beds east of the powerful dyke which crosses the stream nearly due south of Rayhaon. A bed of good coal six and a half inches thick occurs along the right bank dipping north-north-east 13°. It has above it stony coal one foot seven and half inches. Below it come—

	Ft.	In.
Slaty carbonaceous shale	8	0
Good *Coal*	0	4
Slaty carbonaceous shale	0	5
Coal about one foot and six inches. It merges into carbonaceous shale along its strike	1	6
Coal	0	3

The same beds are re-exposed further down the stream, at the place where it flows north-east. The section is—

	Ft.	In.
Stony *Coal* above	1	0
Good *Coal*	0	6
Slaty carbonaceous shale	5	0
Coal	0	4
Slaty carbonaceous shale	0	5

		Ft.	In.
11.	Thick-bedded sandstone	29	0
12.	*Coal*	1	0
13.	Variegated sandstones	13	8
14.	Calcareous sandstone	1	3
15.	Thin and-thick bedded sandstones	72	0
16.	Coaly shale. Dip 68°	3	6
17.	Concretionary argillaceous shale	1	3
18.	Carbonaceous shale	2	8
19.	Micaceo-argillaceous shale	3	5
20.	*Coal*	3	6

Eighty-three yards from this is the mouth of the Bhagalatta.

In the ground between this stream and the Chootooa there is a deposit of kunkur. It has been quarried in order to supply lime for the bungalows building on Jilunga Hill.

The sections west of Puchmo are few and imperfect. Numerous small streams occur, but their channels are invariably filled by sand. A few rocks are seen in the Jhirna Nullah at the boundary.

In ascending order—

		Ft.	In.
(a).	Fault rock.		
1.	Greenish slightly felspathic and micaceo-siliceous sandstone. Dip 60° S. S. E.	39	6
2.	Slightly carbonaceous shale. Dip 50°	15	3
3.	Argillaceous shale slightly concretionary	1	9
4.	Slightly carbonaceous argillaceous shale	0	8
5.	Greenish micaceo-argillaceous shale	3	9
6.	Carbonaceous shale	0	11
7.	Highly felspathic siliceous sandstone, greenish and thick-bedded, containing also boulders	6	9
8.	Greenish, yellow, micaceo-argillaceous shale	1	6
9.	Like No. 7	4	3
10.	Micaceo-argillaceous shales, concretionary in places, with a yellowish green colour	20	0

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	Ft.	In.
Slaty carbonaceous shale	8	0
Good *Coal*	0	4
Slaty carbonaceous shale	0	5
Coal about one foot and six inches. It merges into carbonaceous shale along its strike	1	6
Coal	0	3

The same beds are re-exposed further down the stream, at the place where it flows north-east. The section is—

	Ft.	In.
Stony *Coal* above	1	0
Good *Coal*	0	6
Slaty carbonaceous shale	5	0
Coal	0	4
Slaty carbonaceous shale	0	5

			Ft. In.
Coal	0 9	}	1 0
Ferruginous shale	0 1	}	
Coal	0 2	}	

Carbonaceous shale, then sandstone, &c.

The beds to the east dip 37°. but undulate, and so exhibit various angles, according to the winding of the river.

Mr. Williams' section was made lower down the stream, and nearly north of Layeo. For the purpose of comparing measurements I made one. There is a good deal of difference between us in the details, although we both arrive at nearly the same conclusion regarding the gross thickness of the beds. The coal seam marked six feet on the map shows where the section was commenced.

In descending order—

No.	Bed	Ft.	In.
1.	*Coal* seam, indistinct, probably 6'0" to	7	0
2.	Highly micaceous fine grained siliceous sandstones	4	3
3.	Grey argillaceous shales	1	0
4.	Sandstones and shales like the above, but not distinctly seen ...	9	6
5.	*Coal* seam	3	6
6.	Sandstone and shale	7	6
7.	*Coal* seam, indistinct	2	8
8.	Carbo-argillaceous shale	0	8
9.	Soft micaceo-siliceous sandstone, and soft greenish felspathic siliceous sandstone, alternating. Both of these lose all trace of stratification. They contain a small quantity of lime, and also pieces of silt. The greenish sandstone much resembles the highest beds of the Rániganj series in the Jummoonee nuddee in the Jherria field	62	0
10.	*Coal* (inferior)	1	6
11.	Fine grained sandstone	0	8
12.	Argillaceous and carbonaceous shale	4	3
13.	Slightly carbonaceous sandstone	0	8
16.	Thin-bedded sandstone and brown arenaceous shales	12	0
	Dip 25°		
17.	*Coal* seam	3	5
	Underbed	0	7
18.	Arenaceous shales	9	0
19.	Greenish grey massive sandstones and yellowish slightly calcareous sandstones	32	6
20.	Argillo-arenaceous shale, rippled...	0	2
21.	Grey argillo-arenaceous shales	10	0
22.	*Coal* (inferior). Dip 25°	2	9
23.	Grey argillo-arenaceous shales, with two bands of yellow slightly calcareous sandstones and one bed of carbonaceous shale ...	31	0
24.	Fine grained white and greenish micaceo-felspathic sandstone containing pebbles, with intercalated bands of yellow slightly calcareous sandstone	66	0
25.	*Coal* not distinctly seen	4	0
26.	Slightly calcareous felspathic siliceous sandstones weathering into hollows; intercalated are bands of yellow calcareous sandstones...	50	0
	Dip 15°. Beds strike more nearly N. & S.		
27.	Argillaceous shale	0	7
28.	Fine grained sandstone	1	4
29.	Concretionary argillaceous shales	5	0
30.	*Coal* (Mr. Williams'. 6'0")	2	0
31.	Intermediate beds		
32.	*Coal* (probably Mr. Williams' 0'10")	0	10

		Ft.	In.
33.	Alternating sandstones and shales	31	0
34.	*Coal*		10
35.	Shales and sandstones alternating	14	0
36.	Slightly concretionary carbo-arenaceous shales	0	9
37.	Sandstone	1	0
38.	Carbonaceous micaceo-arenaceous shales	4	0
39.	Concretionary carbo-argillaceous shales with ironstones	9	0
40.	*Coal*	5	0
	This coal is not of superior quality, but it is better than that of the other seams in this river. A twist in strike occurs in the seam; a few beds under it are visible on the right bank of the stream.		
41.	Grey argillaceous shale	4	0
42.	*Coaly* shale	0	6
43.	Sandstone	0	6
44.	Grey argillaceous shale	1	2
45.	Fine grained micaceo-siliceous sandstone	0	9

A reverse dip takes place, so that a synclinal trough is formed. As the river flows transverse to the axis of the trough, the beds which occur on the north face of the synclinal are lower in the series than the ones which we have been studying on the south face. This is a point to remember when going over the ground. The beds enumerated in the following section will illustrate the group, in succession downwards, to within a hundred feet or so of the highest strata in the Bhagalatta.

		Ft.	In.
a.	Felspathic slightly calcareous sandstones, dipping at an angle of 70° S.S.W.		
b.	Fine grained micaceo-siliceous sandstones variegated and thin-bedded. Also arenaceous and carb-shales	186	0
c.	Slightly calcareous, highly felspathic greenish fine grained false-bedded sandstones	81	0
d.	Argillo-arenaceous shale and slightly calcareous yellow sandstone ...	70	0
e.	Like (*c*)	24	0
f.	Brown sandstone	4	0
g.	Carbo-argillaceous shale	1	4
h.	*Coal*	1	6
	Underbed	0	4
i.	Ordinary false-bedded greenish sandstone, Dip 55°	48	0
j.	Micaceo-siliceous argillaceous shales	21	0
k.	Grey very micaceous felspathic siliceous sandstone	14	0
l.	*Coaly* shale	2	2
m.	Grey argillaceous concretionary shales, containing plant impressions	9	6
n.	Thin-bedded greenish grey micaceo-argillaceous shales and sandstones	17	6
o.	Sandstones like (*c*).	78	0
p.	*Coal* seam (uncertain)		
q.	Sandstone	2	0
r.	*Coal*	2	6
s.	False-bedded micaceo-felspathic siliceous sandstone containing a small per cent. of lime	24	0
t.	Argillaceous and carbonaceous shale	4	8
u.	Concretionary argillaceous shales	16	0
v.	Carbonaceous shale and one thin layer of coal	1	6
w.	Sandstone and shale	120	0

The whole of the coal in this part of the section is bad. Below the junction of the left bank of the Bhagalatta and the left bank of the Chootooa are some sandstones, after which the Chootooa turns, and the section is partially obscured. It would have been interesting to have had the rocks exposed throughout, for observations might then have been made on the combined effect of plication and denudation.

The beds are bent over to the north, near the end of the last reach but one before it unites with the Bokaroh. Walking southwards they are passed over in descending order, and they ought to correspond to the ones measured above denoted by letters. I have not mentioned that a coal seam occurs north of the synclinal; it is again seen on the south of it, and measures five feet and two inches.

The section is

		Ft.	In.
1*a*.	Sandstone forming anticlinal		
2*a*.	Very fine grained argillo-siliceous sandstone	3	0
3*a*.	Slightly carbonaceous argillaceous shale	0	3
4*a*.	Grey argillaceous shale	1	2
5*a*.	Fine grained, thin-bedded sandstone and highly carbonaceous shales		
	Dip 25°.		
6*a*.	*Coal* seam	5	2
7*a*.	Grey argillaceous shale	3	0
8*a*.	Slightly carbonaceous argillaceous shales	0	2
9*a*.	Argillaceous shales containing plant remains; also sandstones ...		
10*a*.	*Coal*	0	8
11*a*.	Carbonaceous shale, slightly coaly in places	3	8
12*a*.	Concretionary argillaceous shales	2	6
13*a*.	Sandstones containing plant remains	1	3
14*a*.	*Coal*	0	11
15*a*.	Grey argillaceous shales, concretionary	3	4
16*a*.	Sandstone (indistinct) about	15	0

Then at the junction of the two streams coaly shale, and false-bedded greenish sandstone.

From No. 13*a* I obtained a specimen of the genus *Asterophyllites*.

Plants.

This plant is almost typical of Barákars. The appearance of the thick massively bedded sandstones near Layeo was rather against their being rocks of the lower group, but the occurrence of pebbles, a specimen of *Asterophyllites*, and an apparently

unbroken succession from the lowest bed in the Bhagalatta to the synclinal, all tend to demonstrate that we must regard the sandstones as Barákars.

Westwards from Layeo, there is not any particular point of interest to draw attention to, and by far the best idea of the geology of the district can be obtained by looking carefully at the map. The fault south of Gosee has been already explained; the character of the Barákars has been very well illustrated in the various sections, and it now only remains to describe the local occurrence of coal. I am aware that one or two small streams in which coal probably cropped out to the surface were not examined by me, but this was because they would only have re-exposed seams that I had already observed. It would have been a great waste of time to examine the section of three and four parallel or nearly parallel streams within 50 or 100 yards of each other. Such close work was uncalled for, and therefore on one or two occasions I have used my own discretion as to whether I would examine a certain stream.*

Kheddala Nuddee.

North of Kheddala there is a tributary of the Chootooa, in which one good seam is exposed, the others being too small and too poor in quality to be of any use. The good seam measures 12 feet, and dips at an angle of 12°. The coal burns briskly and freely. Above it in the series is a seam two feet and ten inches thick. Where the river flows south of Eechakdeeh, there are two seams respectively two feet six inches and two feet three inches.

Coal near Kurmutteea.

South-west of Kurmutteea a large bed of carbonaceous shale occurs, dipping 6°; at the base there are three feet of good coal. Between Kurmutteea and Eechakdeeh, a river not marked on the revenue maps exists. In it there are some seams of indifferent coal.

* It must also be recollected that none of these streams were marked on the map.

West of Dooroo.

Three stony seams crop out in a dry water course west of Dooroo. They are of small size.

Two streams south of Bussutpoor flow into the Chootooa on its right bank. In the most easterly of them a seam 15 feet is visible. In the westerly one only a portion of the seam is seen (three feet). This seam dips south-south-east. About 20 yards north of it, we have Carbonaceous shales dipping to the north. This circumstance is one of the best proofs of the fault between the Barákars and carbonaceous shales.

South of Kheddala, there is a *toleh* of the village called Jheerna; north of this village an outcrop or two of coal is seen.

West of Jheerna also there is coal, and a very fair section is exhibited by the Jheerna Nuddee.

East of Ghatotand coal occurs, having a very small dip. All these seams, however, are out of the way, and as the ground is hilly, the coal could not easily be carted.

West of Ghatotand, in the Beessoor Gurha, there are three seams, of which I can give no opinion.

In the area included between the Bokaro and Chootooa there is now only the section of the Jheerna Nuddee, which has not been given. Before mentioning it, however, I will bring up the section of the Bokaro to the point where the Jheerna Nuddee falls into it.

West of the Chootooa, the first coal is visible due north of Teelaya.

Bokaro.

It is thrown by a fault heading north-north-west. The measurement of the seam east of the fault is—

From top to bottom,

	Ft.	In.
Concretionary carbonaceous and argillaceous shales.		
Coal (good)	1	0
Coal (middling)	2	0
Micaceous carbo-argillaceous shales ...	2	8
Coal (at bottom) *seen* ...	2	6

		Ft.	In.
	A dyke appears west of the fault, and then the section is pretty clear.		
1.	For the first 100 yards beds obscure.		
2.	*Coal* seam (indistinct) a few feet.		
3.	*Coal* (good). Dip 70°	2	2
4.	Micaceo-felspathic sandstone	12	0
5.	*Coal* seam	5	0
6.	Carbonaceous shale	1	3
7.	Micaceous sandstone and carbo-argillaceous shales; some of the latter become coaly shale owing to thin layers of coal ...	38	9
8.	*Coal* seam	1	3
	Three hundred yards, then river turns, and section is broken.		
	Another reach of the river exposes beds higher in the section. Dip is west instead of south.		
(*a*).	*Coal* seam. Dip 14° west-south-west	5	9
	A large seam at the mouth of the Juggaysur nullah occurs underneath (*a*). It is not well seen on account of the sand and water in the Bokaro.		

Above (*a*)—

		Ft.	In.
(*b*).	Carbonaceous shales, and arenaceous sandstones intercalated with slightly calcareous thin-bedded yellow sandstones	37	0
(*c*).	*Coal* seam	4	0

	Ft.	In.
Coal (very inferior)	1	0
Sandstone	1	0
Coaly shale	2	0

		Ft.	In.
(*d*).	Ferrugino-arenaceous sandstone	1	6
(*e*).	*Coal* seam	4	5
(*f*).	Areno-carbonaceous shales	4	0
(*g*).	*Coal* (good)	1	3

Dip 14°.

Thirty yards up the river the beds become horizontal; then they dip again to the west, and we get—

(*h*). Sandstones a few feet.

Above these—

		Ft.	In.
(*i*).	Shales and yellow sandstones	10	0
(*j*).	*Coal.*		

These beds become crushed, and nothing is distinctly seen. One hundred and thirty yards up the river, the intermediate beds being principally sandstone, a large seam of coal occurs, the bottom portion of which is of excellent quality. Its dip varies from 11° to 17°. The coal of this seam burns excellently, and is very much superior to any in the neighbourhood, excepting a seam which crops out in the Gosee and Layeo Road, which is the best in the field, as far as I am aware of. The seam at the mouth of the Juggaysur nullah is probably the continuation of this one.

Coal near Gosee.

Bokaro Section, (contd.)—West of the seam in the Bokaro which was stated to dip at 11° to 17° a fault of small throw crosses the river, pursuing the general course north-north-west. Between it and Gosee three or four seams crop to the surface. One of them is accompanied by trap. The angle of dip in the largest seam is 35°.

South of Gosee a seam injured by trap occurs. The village water ghât exposes a bed of carbonaceous shales on one side two feet six inches thick. The beds dip north-north-east. There is east and west flexuring accompanied by small faulting, which give the beds a complicated appearance.

About quarter of a mile west of Gosee coal again occurs and the section in descending order is—

				Ft.	In.
1.	Sandstones.				
2.	*Coal*			2	6
3.	Micaceous sandstones			2	0
4.	Slaty carbonaceous shales			6	0
5.	*Coal*			1	4
6.	Shale			2	0
7.	Coarse siliceo-felspathic sandstone			1	0
8.	Carbonaceous shale			1	3
9.	Felspathic sandstone and carbonaceous shale			9	0
	Small fault running N. and S.				
10.	Carbonaceous shale			0	8
11.	*Coal* seam			20	7
		Ft.	In.		
	Coal	0	10		
	Carbonaceous shale	0	5		
	Coal	0	4		
	Concretionary carbonaceous shale ...	5	0		
	Coal (good)	8	0		
	Coal (poor in quality)	4	0		
	Carbonaceous shale	2	0		
	Total of *Coal* ...	13	2		

The seam is thrown again, and the fault heads in the same direction as before.

The river here bends and exposes beds higher in the series, and we get repeated the whole the strata from No. 10 to No 1.

Above the sandstone No. 1 comes—

	Ft.	In.
Coal	1	4
Carb-arenaceous shale	1	10
Sandstones.		

The beds following are disturbed, and seam No. 11 and its associated rocks are again seen.

The river now turns to the south and the whole of the rocks are completely hid, as far as Pindra or Jheerna Nullah, and still further to the west of it above quarter of a mile. Here a seam occurs dipping north-west at an angle of 52°, thickness roughly estimated at 18 feet.

About 300 yards west of this the upper portion of the group is remarkably well seen, and indeed it is the best section for illustrating the nature of the upper Barákars.

The course of the stream is from east to west, and we have in ascending order—

		Ft.	In.
1.	*Coal*	1	6
2.	Argillaceous and carbonaceous shale	8	6
3.	*Coal*	16	0
	Dip 25° N. W.		
4.	Carbonaceous shales with thin-bedded sandstones	26	0
5.	Coaly shale and concretionary carbonaceous shale	22	6
6.	*Coal* seam	9	0
	Dip 35°.		
7.	Concretionary carbonaceous shale with incipient ironstones and thin sandstones	41	3
	Dip 40°.		
8.	Carbonaceous shale	1	4
9.	*Coal*	5	8
	Dip 35°.		
10.	Sandstone	171	0
11.	Concretionary carbonaceous shales, with incipient ironstones. Coaly shales passing into coal; and slightly calcareous ferruginous sandstones; also thin beds of argillo-felspathic sandstones ...	114	0
12.	*Coal*	2	0
13.	Argillaceous shale, with slightly ferruginous bands	2	0
14.	Sandstone	4	0
15.	*Coal* seam (middling)	6	6
16.	Argillaceous shales, carbonaceous shales and sandstones ...	110	0
	Ironstone shale series.		

The passage of Barákars into ironstones is very distinct here. Returning eastwards to the sections which have not yet been noticed south of the Bokaro, the first to remark upon is that of the Bugjobra.

Bugjobra Nuddee.—This river flows east of Teelaya, and exposes the southern boundary. The bottom bed is an incipient conglomerate; above it come sandstones and shales. The former are not so massively bedded, as they usually are at the base.

A dyke occurs nearly due west of the Teekadar's house; and at the west corner of the river is a small seam. Between this point and the village of Dhakasarum, considerable rolling in the beds occurs, and the tortuous course of the stream brings us in succession upon dips, varying towards nearly every point of the compass.

The middle Barákars are well exposed near Dhakasarum.

The first good coal is seen 230 yards south of the large dyke. There are three seams close to each other. The best in quality is the highest of them, measuring three feet and four inches. 27 yards horizontal across the strike of the beds brings us to a seam of one foot (good in quality). It occurs north of a bend in the stream; 50 yards horizontal from this, and we reach another seam; and then 46 yards further a seam injured by trap. The large dyke crosses a little lower down. North of it there are two more instances met with in which trap accompanies carbonaceous beds, and then a dyke heading east and west, or slightly north of east. The continuation of this dyke is exposed in the Bokaro; then it passes inland, and again crosses the Bokaro, and strikes south of Layeo.

The beds north of the large dyke are carbonaceous shales with ironstones, but they are cut off by a fault heading north-north-east, which causes an upthrow of the Barákars, so that the latter appear and continue steadily to the junction of the Bugjobra and Bokaro.

Fault with trap.—This fault is accompanied by an intrusion of trap, and is the only instance excepting the example, south of Teelaya and west of Ooda, of such an occurrence in the whole of the field.

In the Bokaroh there is evidence of another fault; as in the strike of the beds of this section, we have strata much lower in the series.

West of Teelaya.—There are two nullahs, in which nearly the same sections are exposed. A large seam occurs just before the streams fall into

the Bokaro. Its thickness is nine feet. The beds dip steadily south. As we go up the nullahs two more seams are met with, and then some carbonaceous shales with ironstones. A reverse dip takes place in these beds, and then the section is in descending order. Local dips are seen in this area similar to those in the Bugjobra.

West of Gosee and north of Bokaro.—There is a small river west of Gosee, known by the same name (Bhagalatta) as the one which unites with the Chootooa near Layeo. In it there are some seams, and a dyke is also seen. There is ample evidence of a series of faults varying in direction from north to north by east. They are not of great throw, and are not of much interest except as indicative of an area of weakness. Towards the source of this stream, the middle division of the Barákars is well exhibited, and the deep yellow ironstones of that group crop out on the surface in great abundance.

Boundary north of Juggaysur.—The boundary north of Juggaysur is undoubtedly a natural one, and the regular pebble beds of the Barákars are excellently developed. Several runs of quartz breccia and granite occur; indeed the great number of the latter is quite a feature in the district.

Pseudo-Talchírs.

Underlying the Barákars, along many portions of the boundary, is a very compact reddish green siliceo-ferruginous rock—that is probably gneiss, which has been impregnated to a considerable extent by the elements forming the sedimentary rock. It has very much the appearance of Talchírs.

Seerka Nullah.—I did not take the trouble to measure the section in this river. I merely noted that coal occurred near the boundary dipping at 52° to the north, and that at its mouth the coal inclined towards the north-west.

Jheerna or Pindra Nullah.—In the neighbourhood of Jheerna there are so many rivers to choose from in which to make sections that it is difficult to tell which one to go up. I have, however, chosen to follow

the course of the one which passes nearest to the villages of Jheerna and Ghurkay or Ghurnkeea. These villages are prominent marks and indicate best the locality of the section. The dip of the beds here is slight, and in many instances rolling takes place, so that the large spread of the Barákars can easily be accounted for. Some way north of Ghurkay, we only meet with sandstones, all of which are of Barákar type.

The first coal seen in the river is a small band two inches thick, with concretionary carbonaceous shales above and below. About eight feet lower in the series is a seam two feet four inches. About 200 yards further down the river is another seam four feet, with carbonaceous shale capping it.

The quality is excellent; and when the seam is first seen it is perfectly horizontal. It is exposed four times, and the last time has a south-westerly dip at a very small angle.

Below the coal comes—

		Ft.	In.
1.	Carbonaceous shale	5	0
2.	*Coal*	0	3
3.	Carbonaceous shale with slightly ferruginous bands thickening in places	5	6
4.	Felspathic sandstones	2	0
5.	Concretionary carbonaceous shale	1	4
6.	*Coal* (good)	1	0
7.	Concretionary carbonaceous shale	4	0
8.	*Coal* (good)	0	8
9.	Carbonaceous shale	3	9
10.	Felspathic sandstone	2	0
11.	*Coal* (good)	6	0
	Dip 8°		
12.	Sandstone	1	0
13.	Carbonaceous shale	0	8
14.	*Coal*	2	0
15.	Sandstones and carbonaceous shales		

Thirty yards—stream joined by a small feeder west of Jheerna; in this there is a seam exactly opposite the village of very good quality.

Under it the section is—

	Ft.	In.	
Intermediate beds (about) ...	20	0	No. 13 and upwards.
Coal	1	0	
Carbonaceous shales passing into arenaceous shales (about) ...	16	0	
Coal seam (middling) about ...	2	0	=No. 14.
Sandstones, micaceo-felspathic ...	18	0	=No. 15.

Then Jheerna or Pindra Nullah.

		Ft.	In.
16.	Sandstones, &c.	30	0

Waterfall 8 feet high.

		Ft.	In.
17.	*Coal*	0	4
18.	Concretionary carbonaceous shales	1	2
19.	Sandstones, felspathic	5	0
20.	Slightly ferruginous fine grained sandstones...	6	0
21.	Concretionary carbonaceous shales	7	0
22.	Micaceo-felspathic sandstones	0	10
23.	Concretionary areno-carbonaceous shales	2	2
24.	Sandstone	0	8
25.	Carbo-argillaceous shale	3	0
26.	*Coal* seam	9	1

Dip 8°.

	Ft.	In.
Coal	2	10
Carbonaceous shale ...	4	2
Coal	2	1
Total of *Coal* ...	4	11

		Ft.	In.
27.	Carbonaceous shale	2	0
28.	Sandstones	16	0
	2nd Fall.		
29.	Carbonaceous sandy shales	13	0
30.	*Coal* seam	25	0
31.	Concretionary shales with a small band of coal	7	0
32.	Micaceous felspathic sandstones	10	0
	Dyke.		
33.	Carbonaceous shales imperfectly seen. Where the southern fault crosses is not distinctly seen.		
34.	Micaceo-felspathic sandstone	12	0
	3rd Fall.		
35.	Carbo-arenaceous shales	10	0
36.	*Coal* seam (many parts good)	17	0

This seam appears thicker, but it is faulted and causes a deception. Underneath, sandstones occur, and then the section is obscured.

37. The section becomes clear where the river for the fourth time falls Both above and below the falls coarse felspathic grits occur. The beds here become much contorted.

At the bottom of this fall (which is about 200 yards from the Bokaro) a succession of coaly and carbonaceous shales crop out that extend over 300 feet horizontal.

This area is one in which seams are plentiful, and the quality of many is that of good Barákar coal. The locality is difficult of access however. One circumstance is favorable, and that is the lowness of the dips.

Ghatotand.—East of Ghatotand a river shows the southern fault and a seam or two of coal. West of Ghatotand, the Beessoor-gurha exposes three seams, the one near its mouth is large, and dips southerly.

Section of Bokaro (contd.)—The Bokaro where it enters the field exposes a little nose of pebble beds; then passes exclusively through gneiss, and afterwards re-enters the Barákars west of Foosro. A fault

forms the boundary. This fault is confirmed by the occurrence of a warm sulphureous spring that breaks out on the line of shift. The dip is at first east; but coal is not seen until the beds incline to the north-north-west.

The seam marked seven feet four inches on the map is the lowest in the series. Its details of measurements are, in ascending order,

		Ft.	In.
Coal, middling (not all seen)		6	0
Parting slaty shale		0	4
Coal		1	0
Intermediate beds		23	0
Coal (inferior)	0′ 10″ to	1	0
Carbonaceous shale		0	6
Coal seam (indistinct).			
Intermediate beds		23	0
Dip 15° N. by W.			
Coal seam		6	0

	Ft.	In.
Coaly shale	5	0
Coal (good)	1	0

Then rocks not distinct.

Below the junction of the Bokaro with the Boodah, there is a seam 11 feet thick. Section from top to bottom—

	Ft.	In.
Carbonaceous shale slightly coaly	3	7
Coal (average quality)	1	0
Carbonaceous shale slightly coaly	6	5

The bottom portion of this seam presents an admirable case of intercalation. A very peculiar and well marked bed of sandstone wedges it self in, and a portion of the carbonaceous shale is seen under as well as above it.

The Bokaro does not exhibit anything of interest between this and the Foosro Nullah.

Foosro Nullah.—A few yards from the boundary, there are slightly concretionary carbonaceous shales. About 75 yards from the boundary, a seam has been cut into, but is now filled up with sand. At 180 yards another seam also filled up. The coal is used in Hazareebagh for brick burning, and several Natives have taken contracts to supply the coal. They are now cutting into some of the seams, and it is by them that the beds have been worked, and then abandoned, when the trouble of holing the coal became too great.

Coal used in Hazareebagh.

For 200 yards from the last seam the river is very much obscured; then we come to a bed of stony coal; and the only reason I notice it is because it has been cut into, and because it is near Foosro, and serves as an index of position.

It crops out for 200 yards along the face of the river. Its dip is east 8° and thickness three feet and eight inches. Below it is carbonaceous shale. This coal is only fit for the purpose for which it is employed, namely, brick burning.

The section then becomes—

	Ft.	In.
1. Highly arenaceous sandstones, very fine grained	41	6
2. Carbonaceous shales	24	0
3. *Coal* (being cut into, 1866). Dip 6° to 10°	2	10
4. White felspathic sandstone	4	0

Bokaro River.

The above coal changes in its strike, and then dips south-west. It is worked on both sides of the river.

Bokaro Section (contd.)

Then—

Above No. 4 is a bed of coaly shale that has been largely worked. It dips south at an angle of 10°.

Coarse felspathic quartzose sandstone	26	0
Variegated fine grained sandstone	26	0

Dip S. E.

Concretionary carbonaceous shale...	4	6
Highly felspathic micaceous sandstone containing pebbles ...	34	0
Coaly shale. Dip 6°	25	0
Carbo-arenaceous shale	1	10
Carbonaceous shale. Dip 10°	10	0
Fine grained whitish carbo-siliceous sandstone, rippled	7	0
Coal: in some places coaly shale. Dip 10° S. E.	9	6

Reddish, variegated, coarse grained felspathic sandstones.—It is reversed and dips north-north-west 20°. This sandstone holds steadily as far as the Kujree or Gujree Nuddee.

Kujree Nullah.—The section of this river is imperfect. The boundary is about 15 yards north of the Tapin and Churhee Road. Proceeding down the river, a very stony coal has been cut into, but was abandoned quickly, on account of its bad quality. The beds

incline gently to the south. A little lower down the stream is a bed of coal, two feet six inches. Under, and also above it, are carbonaceous shales. The dip has increased here, and is as much as 15°. One or two other seams occur, but the section is very imperfect, owing to the general occurrence of sand. Just where the nullah joins the Bokaro a large bed of shale crops out. This has also been cut into, under the expectation of getting coal, but excepting in places where little strings of coaly matter occur there is no approach to coal. The dip is north in the Bokaro.

Bokaro section (*contd.*)

Three hundred yards east of the Kujree, the Tapin and Mando ghât occurs. A seam of coal has been cut into where the road crosses. The dips are west and west-north-west, at angles varying from 10° to 12°. None of the seams have any pretence to be called coal seams, but as they contain small strings of pure matter, probably they burn sufficiently well for brick-making. After an interval the dip is north-west, and there is a basin-shaped depression in the beds. A dyke occurs some little way further, crossing the Bokaro. Its extension in the direction of Pindra is plain enough, but there is no trace of it near Mando. West of the dyke is a seam partially injured by trap. The river then runs nearly due east, and flows through sandstones, cutting in one place a gorge, which, although not deep, is instructive in its way, as exhibiting the excavating power of water. The water at the bottom of the gorge is very cool and pleasant to drink, and in the hot months, it furnishes the most interesting portion of the section. The sandstone in the gorge is a highly felspathic silicious stone containing nests of boulders and pebbles, strings of the same, and carbonaceous strings.

Sandstone highly felspathic.

The dip of this sandstone varies in its direction, being sometimes northerly, at others southerly. In the jungle, however, south of the river the dip is north-east.

Implements. It was in this jungle that I found some stone implements, which are now in the Geological Survey museum.

The felspathic sandstone noticed above forms the bed of the river for a long way, as its strike coincides with the course taken by the stream. Coaly shale is seen in one of the bends injured by trap. The next bend of the river again brings in the felspathic sandstone.

After a long interval the coaly shale re-appears, not injured by trap. It is four feet six inches thick. It possesses scarcely any dip. The felspathic sandstone holds steadily on down the stream, worn into hollows of every conceivable shape; pot holes meet one at every step. The generality of them, however, contain no pebbles, and are evidently the result of mere water action.

A large seam occurs nearly west of Ghatotand, or rather west of the mouth of the Beessoor-gurha, measuring 22 feet in thickness. The direction of dip veers about, and from this point to the confluence of the Hoharoo and Bokaro is never steady. The seam itself dips in one portion east and then becomes east-south-east. Above the seam the dip remains steady east-south-east for about half a mile. The angle of inclination varies in amount. It increases in the beds above the 22 feet seam, but when we get to another large seam it decreases again and becomes nearly horizontal. This latter seam is a mixture of carbonaceous shale and coal, but portions of it are worth extracting. The directions of the dip are shown in the map.

The carbonaceous shale group crops out in the river south of this last seam.

Some more seams are seen in the Bokaro, east and west of Suroobera. The beds in the Bokaro are higher than those in the Hoharoo. I will, as there are only a few feet of Barákars exposed in the Hoharoo near Bongahara, unite the two sections.

Moorpa nullah west of Moorpa.—In this stream coal occurs very near the boundary, dipping nearly due north at an angle of 35°. On going down the nullah more seams are seen; the direction of inclination turns to the west, and there is a decrease in the amount of dip to 12°. One seam has been worked. In parts of it, it is fair coal. There is a good deal of iron however in it. A fault cuts it off at one end. This fault is an unmistakeable one, as there is a difference in direction of dip on each side of it, and it is indicated by a natural feature—a fall in the level of the ground, which produces a water-fall. In the Hoharoo the fault is again clearly visible, the ironstones being brought up against Barákars. The fault heads north north-west.

Another river flows east of Moorpa. I did not examine its section minutely. Coal, however, occurs in it.

Hoharoo Section (contd.)—The Hoharoo for the greater portion of its course flows through ironstones, but Barákars are visible at the Bunwar ghât. On one side they are faulted. In fact a series of faults exists here. I have no hesitation in saying that those which I have indicated are clearly established. Of all the faults in the field I cannot speak so confidently.

The dip of the ironstones east of the fault is south-south-east 60° to 70°, whereas that of the Barákars is north-north-east by east 37°.

The following section occurs:—

	Ft.	In.
Sandstone.		
Carbonaceous and siliceous carbonaceous shale	5	0
Sandstone, (variable) ... ... 1'0" to	3	0
Carbo-argillaceous shales	5	8
Coal (impure)	0	10
Fine carbo-siliceous sandstone	4	0
Coaly shale	3	9
Dip 37° N. N. E.		
Variegated carbo-siliceous sandstone and shales	12	0
Concretionary carbonaceous shales	1	0
Slightly calcareous sandstone	2	0
Carbonaceous shales	17	0
The river here turns, and a few of the beds are obscured. The next ones coming plainly into view are thin-bedded fine grained sandstones, some of them are finely variegated. Calculated thickness about	160	0
Coaly shale	5	4

Dip W. N. W.	Ft.	In.
Extremely fine grained pale yellow sandstones	9	0
A small fault lets down this carbonaceous shale, the depth of three feet.		
Carbonaceous sandstone	3	0
Purple felspathic micaceous sandstone	2	0
Carbonaceous shales	3	0
Sandstone (about)	2	0
Carbo-siliceous shales	5	0

Felspathic sandstone at ghat where Ranchee road crosses the river.
On the west side of the Ranchee road the ironstones come in once more.

River east of Mando.—At the mouth of the river, east of Mando, Barákars occur; but after an interval ironstones come in. A turn of the river re-exposes Barákars, and a fault is seen, heading north of west. At the fault is a seam of coal very much twisted and disturbed. Going up the river another seam dipping at an angle of 10° is exposed. The thickness is about 10 feet.

Coal near Bunwar.—South of Bunwar in a small stream which joins the Hoharoo, a seam occurs 10 feet thick.

Coal near Mungurdooha.—A river west of Mungurdooha contains some seams. None of them appeared to be of even average quality, although quite fitted for burning bricks; and so I measured none of them.

Nearly opposite Toeera to the north some seams occur near the boundary, which passes north of the Hoharoo. In the Hoharoo itself two seams are exposed near the western boundary.

Dutman.—Coal crops out north-west of Dutman. And one or two seams in the vicinity of Kodway.

The Barákars are exposed in a river north of Kodway, which is not marked on the revenue map. The dip of the beds is north-east to north-north-east.

I have no other information to afford regarding the localities in which Barákar coal occurs. I am aware that all the outcrops have not been mentioned, and that there are two or three nullahs whose sections I have not referred to. These, however, as was previously explained, were only at a short distance from other rivers, whose sections I had given, and I

judged it would be almost a waste of time to run sections in both. Scarcely any of the smaller streams which I have mentioned were marked on the map furnished to me. I had therefore the task of plotting them forced upon me in addition to my own work. The length of time thus involved in making as approximately an accurate map as I could, rendered it imperative that I should employ my judgment upon certain occasions, so as to distribute my time to the best advantage. Thus the outcrops of some few seams in this district may not have been traced with the same care as those in the more important fields to the east. From the number of seams that have been described in the report and marked upon the map it may, however, be conjectured that very few could have escaped detection.

Maps.

I may here remark that every stream west of Layeo has been altered, or mapped for the first time by myself. From the junction of the Bokaro and Chootooa to that of the former river and the Hoharoo, every nuddee has been put in by me. The Bugjobra was measured carefully throughout, from the boundary to its outfall into the Bokaro. The Chootooa has been entirely altered. And the Bhagalatta, Sut Nuddee, and others of its tributaries which had all been omitted, have now for the first time been laid down. The Chumargurha, the Foosro nuddee, the Mungurdooha nuddee, the Moorpa nullah, the Kubode nullah, the Gobinpoor, and the Mando nullahs are all new. The Hoharoo has been entirely newly plotted. The Bokaro itself I found necessary to replot, otherwise I could never have mapped its seams correctly.

East of Loogoo hill; the labour has been almost the same.

The coal in the Barákars is much the best in the field; but it is not to be compared in its general quality with that obtained from the same group in the Jherria Field. Individual seams are good, especially one referred to occurring

Economic.

on the road between Layeo and Gosee. Judgment can, however, scarcely be given on rocks which are even more imperfectly exposed than those in the Jherria and Raneegunj districts; and, to accurately test the value of each seam, pieces of coal ought to be procured from a depth where extraneous matter has not been able to reach to. Seams occurring in the Barákars may always be looked upon as possibly able to yield fuel of very good quality; and when the time arrives for the further development of the resources of this field, assays will readily determine the power of each coal. The spots where coal occurs have been pointed out, and those seams which will probably be good are mentioned.

Ironstones.

The ironstones of the middle Barákars may hereafter be utilised. A few ironworks are to be met with in the district, but they only supply local demand. The great centre of the iron manufacture is the Karunpoora district, where in an area of 500 square miles, there are more than 200 furnaces.

Section 2.—THE IRONSTONE-SHALE GROUP.—This group is typically developed in this field; and its existence cannot be overlooked by the most unaccustomed eye.

Different from what we see in the Jherria Field, the middle group is made up of distinct carbonaceous shales with just as distinct ironstones; and as they assume a thickness of at least 1,500 feet, they form a well marked geological horizon in the Damúda series.

There is no unconformity between them and the Barákars, where an unbroken section is exposed of the two groups; but near Toeera and Bongahara, there appears to be something of the sort. Faults, however, occur in the neighbourhood where this seeming unconformity exists, so that the evidence is not thoroughly reliable.

The Ironstones are exposed near Goomea, but are most markedly developed in the Bokaro and Hoharoo.

The Rániganj group overlaps them in the neighbourhood of Hosir and Sarum, and north of Loogoo hill they are overlapped by the Panchéts.

North of Suroobera.

Suroobera.—Near Suroobera they dip to the north-east, increasing in the angle of inclination from the bottom upwards, from 36° to 48°. The Bokaro runs in a north-easterly direction, and exposes the beds, cutting them directly at right angles to the strike.

The lithological nature of the rocks is clearly visible. It is observable that although the series is mainly composed of carbo-argillaceous shales, with arenaceous ironstones, there are many beds of sandstones occurring at pretty regular and short intervals. The sandstones are generally slightly calcareous and highly micaceous and felspathic, resembling in almost every respect the yellow sandstones of the Rániganj group. In fact commencing towards the upper portion of the Barákars, and throughout the middle and upper groups, these sandstones are persistent.

The shales are usually grey, and not so impregnated with carbon as those of the Raneegunj Field. In the Hoharoo, however, they are deeper coloured than those in the Bokaro.

In the lower portion of the group, the ironstones are replaced by very fine whitish siliceous and slightly calcareous sandstones, often yellow. These differ from the yellow sandstones both of the Rániganj and Barákar groups. Those of the former being more calcareous; whilst those of the Barákars are often slightly reddish, contain pieces of mica, and fragments of stems and leaves, and present a bluish appearance on the fractured surface.

The section of a series so uniform throughout, is scarcely requisite. The upper portion of the group is exposed near Bussutpoor, and any one

anxious to study it has a good opportunity afforded him. The thickness visible is 680 feet, made up as follows :—

		Ft.	In.
1.	At top slightly carbonaceous siliceous shales, concretionary, becoming more argillaceous as we descend in the section, and commencing to contain ironstones.	424	0
	The dip increases from an angle of 37° to 50° and then decreases.		
2.	River bends, and then shows a further thickness in descending order	250	0
	Dip 28°-30°.		

The rocks are then obscure, and some way down they are cut off by the fault referred to in the description of the Barákar group, and along which springs break out.

North-east of Bussutpoor Ironstones are observed, dipping south-south-east. The cross-fault which I have put in cuts off the east and west one; it is not clear; and how it ends to the south is a point which I could not satisfactorily determine.

The Ironstones everywhere seem to be faulted, and I was about to add, are more faulted than the Barákars. This, of course, is not the case; for the throws affecting the upper beds will affect the lower (I speak of regular throws, that is, faults passing down deep, no matter what the amount of shift may be); but faults are so much more easily recognised where the Barákars and Ironstones come into contact, than where they are confined to one series, as fully to account for the apparently greater number of faulted boundaries of the middle group.

In the Hoharoo the typical section of the Ironstones occurs. They are much flexured, and exhibit a variety of dips, in direction and amount.

South of Goomea the Ironstones which occur are not so typical of the group. They are deficient in carbonaceous colouring matter, and the Ironstones are more arenaceous than usual, and do not form the main body of the group, as in those places where it is more characteristically developed. The out-crops of the beds near Khoodgudda exhibit a very distinct curvature, and their edges can be walked upon. Nearly south of Goomea, the strata are cut off by a small fault.

Economic.—The economic value of the Ironstones is well known. In the Bokaro Field the stones are rather siliceous; and the Native workmen seem to prefer the iron from the middle Barákars for smelting.

In the Karunpoora Fields the ore worked is almost exclusively that of the lower group.

Section 3.—The Ranigani group.—This group occupies the area between the Bokaro and the Dhungadugwa rivers. The beds dip on the whole to the west, towards the basin in which the Panchét series rests. There is no difference in lithological character between the rocks of this group as developed in the present area and those of the Jherria and Raneegunj districts, to the descriptions of which reference need be made. The only facts of any interest to record in connection with the group here are, the unconformity which it exhibits to the lower groups of this series, and the general absence of any serviceable beds of coal. The unconformity is best seen in the neighbourhood of Hosir and Sarum, where the Ironstone shales are so completely overlapped that the Ráníganjs rest directly upon the Barákars.

In the Jherria Field, no unconformity was made out between any of the sub-divisions of the Damúda series, but Mr. W. T. Blanford, in his report on the Raneegunj area, speaks of a break between the lower and middle groups.

The observations in this district tend, on the contrary, to show that there is here a more intimate relation between the Barákars and the Ironstones, than between the latter and the Ráníganjs; and that in fact unconformity exists only between the middle and upper groups.

The Ironstone shales in the Karunpoora Field, thin out completely; and it is questionable whether they ever set in again further to the west; the mode of occurrence of the group suggesting that, although spread over a considerable area, it is comparatively local, and confined to the coal fields of the Damoodah valley.

The best sections of the Ráníganjs, where the rocks are typically developed, occur in the Dhungadugwa and Dhurdurwa nuddees.

Dhungadugwa nuddee.—In this river the Ráníganjs are brought into contact with the Barákars by a fault. The most prominent beds are alternations of purplish and yellow ribboned calcareous sandstones, with white felspathic siliceous sandstones. As we proceed up the nuddee, and trace the rocks in ascending order, the calcareous element is seen to decrease; and we have sandstones more especially consisting of the elements quartz and felspar. In many cases quartz is the chief ingredient. The dip is high, never decreasing below 50°. Above where the road from Layeo crosses, the section is very imperfect. A seam of worthless coal occurs opposite Hurdeeamo, dipping west-north-west 45°. Above it is a plant bed, in which *Schizoneuræ* are very numerous.

The highest strata of the group are carbonaceous shale and thin micaceous sandstone, dipping due west and conforming to the Panchét series. ... ...

Dhurdurwa nuddee.—The relation between the Ráníganjs and Barákars is not so distinctly marked here as in the Dhungadugwa, the junction not being visible; the first rocks distinctly exposed are shales, calcareous bands, and sandstones uniformly fine grained and compact, like those of the upper group.

Coal.

Two very impure and small seams are seen south of the Kodwa and Sarum road: and near the road there are two beds of good coal, one about 20 yards south of it 4 feet thick, and one north of it.

Two more seams occur above the junction of the tributary of the Dhurdurwa, but they are of no commercial value,—both on account of their inferior quality and the high angle at which they are inclined.

Towards the upper portion of the section there is an abrupt decrease in dip; and the sandstones change their colour from yellow to a decided green. At first sight they give the idea of being Panchéts; but they are

too compact, and do not contain mica, which is almost an invariable constituent of the sandstones of the lower Panchét group. Resting immediately upon these questionable beds are green micaceous shales. From this point the rocks are undoubtedly Panchéts; and the sandstones become less compact, more micaceous, and more decidedly green.

Pindra.

There is one other section in which coal occurs, that of the river between Pindra and Toolbool. The unconformity of the Panchéts and Ránigaujs is more apparent here than in either of the two streams mentioned above, which flow into the Damoodah.

Rániganj beds are exposed west of Bussutpoor in the Chootooa. To the north they are faulted against Talchirs and crystalline rocks. Some coal is seen about 500 yards south of the boundary.

In descending order—

		Ft.	In.
1.	*Coal.* Dip 25° north-west	0	6
2.	Fine grained variegated sandstone	5	0
3.	Carbonaceous shale	3	8
4.	Variegated sandstone	2	2
5.	*Coal*	0	6
6.	Variegated fine grained sandstone	6	8
7.	*Coal* seam	2	10
8.	Intermediate beds	105	0
	Dyke east-north-east; width 9 feet.		
9.	Greenish, grey, massive sandstones, compact, fine grained, and slightly calcareous. Some are ferruginous. Intercalated with them are concretionary greyish shales	180	0
10.	Ironstone-shales group.		

In the Tapin-Pindra nullah two seams occur, but I have only thought it worth while indicating one. They are both nearly worthless owing to their bad quality.

Economic.

None of the coal noticed in any part of the field belonging to the Rániganj group is of real value; and with the exception of the seam in the Dhurdurwa, south of the Kodwa and Sarum road, and that in the Pindra and Toolbool nullah, the whole may be set down as useless, except for the very coarsest requirements.

There is a covering of yellow calcareous clay usually spread over the surface of the sandstones, and which is used by the Natives whenever they require lime. In many places this clay is eaten out into the most perfect imitation of miniature mountain ranges and table lands, with steep scarps, often 12 to 20 feet high.

Kunkur.

IV.—The Panchet Series.

This series has been divided into an upper and a lower group, on lithological grounds; the lower comprising green micaceous shales, red clays, and massively bedded friable sandstones, usually fine grained; whilst the upper consists essentially of conglomerates and coarse sandstones.

Probably there is unconformity between these two divisions; but the contact of the two, which always occurs on hill sides, is so invariably obscured by jungle and fallen masses of rock that hitherto it has been impossible to ascertain, with any degree of certainty, whether a break does or does not exist. It may be found necessary hereafter to draw a difference of a stronger degree between these two groups, and elevate each into a series; retaining the lower as the Panchéts, and possibly referring the upper to the Mahadevas of the Nerbudda Valley.

Section 1.—Lower Panchet Group.—This group, forming the base of Loogoo hill, is made up of green micaceous shales at the bottom, succeeded by massive green silty sandstones, and these by red clays alternating with beds similar in character to those at the base. The fineness of texture throughout is remarkable, and quite at variance with that which prevails in the upper group.

In every section the rocks of this series are distinguishable with but little difficulty from the Rániganjs, even when a green colour pervades the strata of either group. They are always highly micaceous and friable; and possess a quasi-schistose structure when represented by shales; and when represented by sandstones, they are soft, massively

bedded, and always micaceous. The Ráníganj shales are well laminated; and the sandstones are usually compact and brittle on account of the lime contained in them.

The stamp-rocks are the red clays found towards the middle and in the upper part of the group. The best exposure of them is in the neighbourhood of Jurwa, to the north of, and in the bed of the Dhurdurwa river. The following section made by Mr. Ball and myself in that stream, will show the composition of the lower Panchéts, and exhibit the proportion that the green and red clays bear to the other rocks of the group. The entire course of the river was plotted, from the Kodwa and Hurdeea ghat to the point where a beautiful water-fall occurs, as the stream issues from the hill, and commences its tranquil flow through the plain.

In ascending order—

Ráníganj beds.

		Ft.	In.
	Grey argillo-concretionary shales, with ferruginous bands; also grey sandstone		
	Fine grained greenish grey arenaceo-felspathic sandstone like Panchéts ...		
	Panchét beds—		
1.	Green micaceous silts, with a few hard bands	57	0
2.	Friable sandstone, with less mica than usual	17	0
3.	Green silt, as No. 1	20	0
4.	Sandstone as above, but more micaceous	46	0
5.	Green silt shales, with harder bands than usual	22	0
6.	Greenish, massive, fine grained sandstone containing portions of silt (the constituents mica, silica, and felspar equally represented) ...	128	0
7.	Green silt shales	41	6
8.	Greenish sandstones more micaceous than the last	42	0
9.	Green silt	1	8
10.	Sandy flaggy silt	0	10
11.	Green silt	2	3
12.	Thick bedded yellowish green sandstones	76	0
13.	Sandstone, yellow, micaceous	46	0
14.	Green shales and sandstones	55	0
15.	Green shales and yellow sandstones about equally divided ...	115	0
16.	Massive sandstone	23	0
17.	Green silt	2	0
18.	Sandstone	6	0
19.	Green silt	0	10
20.	Sandstone	2	0
21.	Green silt	1	0
	Carried over ...	705	1

		Ft.	In.
	Brought forward ...	705	1
22.	Sandstone	17	0
23.	Green silt	6	0
24.	Sandstone	12	4
25.	Green silt	1	0
26.	Sandstone	1	6
27.	Green silt, with hard band	2	0
28.	Greenish sandstones; some very felspathic, with thin intercalated bands of silts	79	0
29.	Green and red silts. Dip 18°	14	0
30.	Sandstones	17	0
31.	Green and red silts (layers alternating)	1	6
32.	Yellow micaceous sandstone falsely laminated	6	0
33.	Red and green silt beds	7	8
34.	Sandstone	10	0
35.	Red and green silt beds (containing strings of lime)	10	0
36.	Yellowish green sandstone	4	9
37.	Red and green silts	3	2
38.	Yellow friable sandstone	18	8
	Beds hid in reach consist of—		
39.	Sandstones (calcareous) about	30	8
40.	Red clay	3	0
41.	Sandstones (calcareous)	180	0
42.	Red and green silts	2	0
43.	Sandstone falsely laminated	15	0
44.	Red and green silt	8	0
	River here runs along strike, and section is repeated—		
45.	Yellow, very friable sandstones containing lenticular masses of red clay	13	0
46.	Red clay not distinctly seen		
47.	Intermediate beds (calculated)	30	0
48.	Sandstones	30	0
49.	Sandstones (indistinct)		
50.	Sandstones, deep blue, green and yellow	52	0
51.	Red clay	4	0
52.	Yellow and green sandstones	45	0
53.	Sandstone, with evidence of included red clays	76	0
54.	Sandstone	38	0
55.	Red clay indistinct in river well seen in small stream on right bank ...	20	0
56.	Indistinct (calcareous)	85	0
57.	Sandstone	30	0
58.	Red clay. Dip 12°	2	0
59.	Sandstone	31	0
60.	Red clay	8	0
61.	Sandstones	84	0
62.	Green sandstone	20	0
63.	Intermediate beds (about)	70	0
	Waterfall		
	Total ...	1793	4

Above the waterfall we have, I think, the boundary of the upper Panchéts.

This opinion is based upon no stratigraphical evidence, but merely on the distinctness in mineralogical composition between the sandstones above the fall, and those in the plain below.

The lower Panchéts have been proved to be unconformable to the Damúdas.

To the immediate west of Loogoo hill overlap is so complete that they rest directly upon Barákars.

Near Pindra and Toolbool the unconformity between the series is very distinct; the underlying rocks having an angle of 25° to 30° whilst the upper dip at an angle of 15°.

I was disappointed in all my endeavours to discover reptilian fossil remains. They would seem to be entirely confined to the Raneegunj area. The description of the fossils which were procured there, and the discussion of the conditions of deposition of the series, has already appeared in the Palæontologia Indica, so that no remarks of mine are necessary on these subjects.

Dykes rare.

There is a marked absence of igneous intrusions into the lower Panchéts of this district as compared with the Raneegunj area: only one dyke penetrates the group near the village of Koiladeeh.

Section 2.—Upper Panchet Group.—This group is quite distinct, as I have previously said, from the lower Panchéts, being composed almost exclusively of conglomerates, grits, and coarse sandstones, strongly impregnated by iron, and possessing usually a reddish colour. Red argillo ferruginous shales are intercalated; and in these are found the very few and invariably indistinct vegetable remains of the series. The sandstones are wholly devoid of any fossils; and as the greater part of the group is made up of them, the upper Panchéts are peculiarly characterised by the absence of organisms.

The mineral characters of the sandstones are different from those of any of the series hitherto described. The matrix is highly ferruginous and siliceous, and contains pebbles of perfectly pelucid quartz imbedded in it. Throughout the whole of the upper Panchéts, there is a great display of iron; and many of the sandstones are so hardened and compacted by it, that they ring loudly and clearly whenever struck. Usually the sandstones are strongly jointed. This character is rendered prominent by the sides of the joints becoming coated with iron, which hardens them and consequently causes them to stand up higher than the main surface of the bed. The true relation of this group to the underlying Panchéts cannot be definitely settled until its strata are traced across the country, and brought into connection with their supposed representatives. If, however, lithological character could be trusted, there would seem to be a probability that the upper Panchéts of this field, of the Raneegunj, and of the Karunpoora, are the equivalents of the rocks described in the report of the Nerbudda Valley as Mahadevas.* The physical contour of the hills in the two areas is also similar.

Mineral characters.

With the above brief notice of the highest rocks in the field, the more purely geological portion of this Memoir closes. It was considered premature to enter into a discussion as to the probable ancient geography of the country occupied by the coal measures, until a larger area of ground had been surveyed, and a more ample array of facts collected.

V.—Economic Summary.

Dr. Oldham has already, in the return of the coal resources of India, called for by the Secretary of State for India, alluded to the probable amount of available fuel which the Bokaro Field can yield, namely, 1,500 millions of tons. The whole of this coal is furnished by

* Memoirs of Geological Survey, India, Vol. II.

the Barákars; the Ránigangs being, as intimated when writing of that group, incapable of supplying any serviceable coal. This decrease in the value of the Rániganj group, as a coal bearing series, was noticed in the Jherria Field; and from thence westwards, it has been determined that its importance comparatively to the Barákars is exceedingly small.

The most productive portion of the field lies between the river Koonar and the eastern boundary. It is in that area the largest coal seams crop out, and that the dips are most favorable. Coal has of late years been regularly cut near the villages of Churhee, Foosro, Tapin-Pindra, and Bongahara, to supply fuel for burning bricks in Hazareebagh; and some has even been carted to Gya; but, as already stated, the worst and most stony variety has been invariably chosen by the Native contractors. Among the fields of the Damoodah Valley, which have already been examined and reported upon, the Bokaro stands third in order of importance.

Sandstones.—For many of the tombstones in the cemetery at Hazareebagh, and for the flooring of the barracks, sandstone slabs are obtained from the Talchir series in the Boodah nullah, near Indra Jurbah. More care should be taken in the selection than is usually done, to procure stones free from any silt galls or layers of silt. In the burial ground, the effect of weathering is noticeable on the tombstones; and many of the inscriptions are almost effaced where the letters have been cut into the clayey parts of the sandstone.

MEMOIRS

OF THE

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The RAMGURH COAL-FIELD, *by* V. BALL, B. A., *Geological Survey of India.*

CONTENTS:

INTRODUCTION.

Position of Coal-field.

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The only recorded geological notice of this field is contained in one of the late Mr. Williams' papers. In the year 1848 he paid it a flying visit when, from the fact of its vicinity to the old town of Ramgurh, he gave it the name

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which we retain as above. Impressed, owing to the inferior quality of the coal which he saw, with a belief as to its unimportance in an economic point of view, he appears to have given most of his attention to the more productive field lying to the north of it.

Physical features.

A brief enumeration of the principal physical features of the country surrounding the coal-field will not inappropriately precede its geological description.

The tract of country which includes the Ramgurh and Bokaro fields contrasts strongly with both that on the north and that on the south. Though by no means devoid of elevations, there is still a general flatness of feature prevailing throughout.

On the north, on the one hand, there are the Jilunga and other ranges of hills, and the remarkable plateau upon which the Station of Hazareebagh is placed; and on the south a well defined scarp which bounds the hilly country included in Chota Nagpoor.

Rivers.

Damoodah not suitable as a means of carriage.

The principal river is the Damoodah or Deonud; outside the area of the coal-field it is characterized by having sandy reaches from one-third to half a mile wide, and from one to two and sometimes even three miles long. Within the coal-field, however, the bed is much narrower and frequently so rocky as effectually to settle the question of the unsuitability of the river as a means of conveyance for either timber or coal.

Tributaries of Damoodah.

The tributaries of the Damoodah within the limits, or in the immediate vicinity of the coal field, are of trifling length; they are, however, very numerous, owing to which circumstance, it frequently happens, that a few hours heavy rain is sufficient to convert its otherwise narrow stream into a raging torrent, which can only be forded with a considerable amount of risk.

Watersheds.

North of this portion of the Damoodah under consideration, the watershed follows a line nearly coincident with the southern boundary of the Bokaro field. On the south, the range of hills alluded to above constitutes the watershed which separates the tributaries of the Damoodah from those of the Cossye and Subunreekha.

Jungle.

The jungle which covers the greater part of this area is low but dense* and in some places only passable with great difficulty.

Villages.

The villages, with the exception of those near the high roads, are very poor, many of them being mere clusters of rude hovels surrounded with small patches of cultivation, which are only by constant care kept free from the encroachments of the surrounding jungle.

People.

The people are chiefly the lower castes of Hindoos with a rather large proportion of Sonthals and a sprinkling of Coles.

I.—General Geology.

Character of coal-field.

Although by far the smallest of the Damoodah valley coal-fields, which have as yet been visited by the Geological Survey of India, and though of no great promise in an economic point of view, still the Ramgurh coal-field possesses geological features which in their bearing upon the general questions of the mutual relations of the rocks composing the Damúda series are of considerable interest.

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* Note.—The natural orders most abundantly represented in these jungles are *Rhamnaceæ, Apocynaceæ, Ebenaceæ, Anonaceæ, Euphorbiaceæ, Loranthaceæ, Lythraceæ, Combretaceæ, Sterculiaceæ, Dilleniaceæ* and *Papilionaceæ*. Besides these however almost a hundred orders might be enumerated, amongst which the plants found here are divisible.

Area.

The total area of this field does not exceed forty square miles; its greatest length in an east and west direction is fourteen, and its greatest width north and south about eight miles.

Western portion disturbed.

Towards the western boundary, or in the neighbourhood of Ramgurh, the rocks have been much disturbed and thrown by faults. In the remainder of the area however, they have only been to a small extent affected in this way.

South boundary, a fault.

As in all the other Damoodah valley coal-fields hitherto described, the southern boundary, or the chief part of it, has been formed by a fault. Its maximum downthrow, has been sufficient to bring down but a fraction of the full thickness of upper Damúda rocks to a level with the metamorphic series; indeed, perhaps, strictly speaking, the existence of these beds at present is more directly due to a cross fault, as will be explained in the sequel.

Panchét series absent.

No trace of the Panchét series remains, all having been swept away by the denuding forces, from the full action of which they were unprotected.

Thickness of groups.

Owing to the peculiar way in which the rocks have been cut off by the southern fault, it is extremely difficult, except in the case of the Ironstone-shales, to estimate, with any degree of certainty, the thickness of the several groups.

The following is as near an approximation as can be made:—

1.	Talchír series	...	850—900	feet.
2.	Damúda „			
	Barákar	group	3,000 ?	„
	Ironstone-shales	„	1,200	„
	Ráníganj	„	?	

II.—Talchir series.

Rocks well developed.

The rocks which compose this series are all well represented in the Ramgurh field; although occupying an area which is small as compared with those of other fields, still good sections are abundant in which every variety of bed, from the silt-shales to the boulder-conglomerate, is found.

The lithological characters of these rocks having been fully detailed in previous memoirs, it is unnecessary to repeat them here.

Lithological characters.

A reference to the map will clearly show to what an extent the Talchír rocks have been overlapped by the lower Damúdas or Barákars. Throughout nearly half the extent of the natural boundaries, Barákar rocks are found resting immediately upon the gneiss. This, to a certain extent, a proof of unconformability is not always a reliable one. That the Talchírs were denuded before the deposition of the Barákars is, however, satisfactorily proved by the occurrence, near the village of Gopo, of a sandstone belonging to the latter group which contains rolled fragments of green silt-shales, unmistakably derived from Talchír beds.

Barákar, unconformable.

The largest and best exposure of Talchírs occurs in the northern extremity of the field in the neighbourhood of Poonoo. The principal rock there is the boulder-conglomerate: such of its outcrops as were seen seemed to indicate a nearly horizontal bedding; the exposed portions are constantly undergoing a process of disintegration, and the surface of the ground is thickly strewn with the liberated gneiss and quartzite boulders, so much so indeed as to interfere materially with the cultivation of what would otherwise be very fruitful soil.

Best exposure of Talchírs.

In a stream north of Poonoo a section discloses a thick bed of sandstone resting on the conglomerate; it is fine, even, and close in texture, and would prove to be, I have no doubt, a very useful building stone.

Building stone.

The road from Poonoo to Paloo passes through several streams in which good sections of the lowest beds are seen. Although the boundary here is distinctly natural, still within a few feet of it the shales are inclined at an angle of 30°.

Sections of Talchírs.

The following is a section measured in the first stream which crosses the road:

Gneiss.	Ft.	In.
1. Boulder conglomerate	9	0
2. Thin Grey argillaceous shales	4	6
3. Silty bed, much distorted, contains scattered pebbles.	3	0
4. Bluish grey flaggy beds, exhibiting concretionary structure; and purple and grey shales, the former much jointed. 5. Thin grey shales 6. Flaggy grey shales 7. Same as No. 4	52	6
	63	0

Remainder of section obscure.

In order to show that the characters of these rocks vary within short distances, I shall quote one other section taken in the neighbouring Paloogudha river:

Gneiss.	Ft.	In.
1. Boulder conglomerate, a portion only seen		
2. Bluish argillaceous flags, dip 10° E, covered up	?	
3. Greenish thin bedded sandstones	6	0
4. Thick silty beds containing a few boulders of gneiss ...	5	10
5. Fine grained greenish and yellow sandstones ...	9	0
6. Thicker beds ditto	5	0
7. Conglomerate, a purple silt matrix with small fragments of gneiss	2	3
8. Bluish-grey shales	6	2
9. Grey shales	52	0

Boulder-conglomerate not always at base.

In some of the other sections met with in this neighbourhood, the boulder conglomerate did not occur at the base, silt-shales having been found resting on the uneven surface of the gneiss.

Other exposures of Talchírs.

At various points along the northern boundary of the field, small outcrops of Talchír rocks occur; the details respecting them are not of sufficient interest for further notice here; their position and relative importance will be best appreciated by a reference to the map.

The southern boundary of the field having been formed by a fault, the course of which lies through higher rocks, we do not find Talchír outcrops so abundant as on the northern; of those which do exist, the one of most interest is found near the Poonoo and Burobing road where it crosses the Damoodah. It is traversed by the fault which occupies the channel of the river, and has here exercised its minimum throw.

In the Bhera nuddee, west of the village of Peprajura, there is a thickness of upwards of seventy feet of shales with a boulder-bed at the base.

Patch of Talchírs separated by fault.

On the eastern boundary of the field a north and south fault has separated a patch of Talchírs from the main mass. This patch would doubtless have been denuded away, but that a small cross fault has let it down on the north. The point of junction of these two faults is marked by an increased development of fault rock which forms a small hill.

In the Bhera and Damoodah rivers small outlying patches of silt filling up cracks and hollows were observed.

Alteration of shales.

Sometimes the shales which rest immediately upon the gneiss have undergone alteration, silica having replaced some of the argillaceous constituents of the rock.

Concretionary structures.

In one of the sections given above, the occurrence of concretionary structures was indicated. These nodules are generally in the form of compressed spheres formed of a series of successive layers. I was unable to discover any nucleus in any of those which I examined; nor did they exhibit any trace of lime on the application of acid.

Boulder conglomerate.

The boulder conglomerate which occurs at the base of these rocks has given to the series an interest in the sight of all observers which it could never otherwise have

possessed. The manner of its occurrence in this field tends further to endorse the truth of the theory now pretty well established of its being a shore deposit.

Origin.

The characters which it exhibits and which separate it from all the other rocks of the series, indicate the presence, at the time of its formation, of certain conditions which were not continued throughout the period. These conditions were the existence of boulders and weathered masses of gneiss, the accumulation of ages, which formed a talus resting on the flanks of the metamorphic hills. Upon this talus, as the waters advanced over the sinking surface, silt was gradually deposited; and when it was covered up, the formation of silt-shales and sandstones proceeded without interruption; the hills still forming islands, or in the case of ranges, the boundaries of estuaries.*

III.—Damuda Series.

Lowest beds.

Section I. The Barákar group.—Resting unconformably upon the Talchírs, as we have shown, are found the rocks which constitute the Barákar group. The lowest beds—those either immediately above the Talchírs or else over-lapping on to the gneiss, are most frequently pebbly conglomerates, in some few places however we find whitish, often false-bedded, argillaceous sandstones at the base. Again there are rocks occurring at certain junctions, whose lithological characters are intermediate between those of Talchírs and Barákars; these are of unimportant extent and thickness, and never involve a question of more than a few feet.

* In parts of the adjoining district of Maunbhoom, considerable deposits of alluvium occupy many of the valleys. I have occasionally found in this alluvium badly developed boulder-beds; but where we would naturally look for the best developed examples, *viz.*, at the foot of the hills, we are hindered by the want of sections sufficiently deep. The general appearance of this deposit is such as to force on any observer's mind the conviction that the conditions which existed during the Talchír period have been repeated in comparatively recent times. At the present day there is a talus at the foot of many of the hills, which, if the country were again submerged, would furnish the principal materials of a very considerable boulder-bed.

Overlap.

Commencing to examine the Barákar rocks upon the eastern boundary, we find that throughout the greater part of it they have over-lapped the Talchírs. This is very distinctly exemplified in a section seen in the Damoodah about one and a half miles north-west of the village of Heshapoora, where a conglomerate, consisting of small white quartz pebbles bound together in a matrix of white felspar rests upon the gneiss.

The following is the section.

		Ft.	In.
1	Conglomerate, Dip 40° N. W.	25	0
2	Sandstones with bands of pebbles	114	0
3	Carbonaceous shale, possibly some *coal*	7	0
4	Siliceous sandstone with pebbles	4	6
5	Interval, no rocks seen	0	0
6	Sharp sandstones	91	0
7	Carbonaceous shale, parts coaly	6	2
8	Grits and sandstones	13	2
9	Thin-bedded sandstones and carbonaceous shale	14	
10	Sandstone	13	
11	Carbonaceous shales, slightly coaly	40	
12	Grits: nearly horizontal		
13	Conglomerate	?	
14	Grits with conglomerate bands	?	
15	Carbonaceous shale	4	0
16	Sandstones	?	

Coal seam with curved outcrop.

After this the river follows the direction of the curved outcrop of a coal seam which dipping first to west passes round by north until the last dip seen is nearly due east. The total thickness of this seam, including some bluish carbonaceous shales seen in the bank above, is probably not less than thirty feet, with a general dip of 10°. The burnable coal contained is in bands of from two to ten inches thick; the remainder of the seam consists of hard, slightly coaly shale containing runs of ironstone. Below this are two seams having a dip of 12° to the East; the higher one contains some good coal. Here as elsewhere in this virgin field where the coal is sodden by water or half covered with sand and has never been cut into it would be impossible to speak with any degree of certainty as to the value of individual seams.

Beyond these seams the river bends about, following the changes in strike of the grits and sandstones, and no more coal seams are exposed until the mouth of the Gunkea river is reached; at this point the sandstones, together with several coal seams, are bent into a synclinal basin. Subsequent crushing and faulting have so disturbed this arrangement that it is difficult to trace out the separate seams along the edges. The following are the principal which can be detected: at the top of the north and south reach of the river is one consisting of 2 feet of coal, dip E. N. E. 10°; below this are two seams which are much broken up and are only seen under isolated masses of sandstone which form islands in the bed of the river. On the other side of the basin two distinct seams occur, one dips at first to N.N.W. from which it bends round to W.; it contains 4 inches of coal. Above it is a thick seam of coal and shale with dip to W.; this seam is probably the one seen again in the Gunkea river where the section exposes 5 feet of good coal.

Synclinal basin.

Several other badly exposed seams are seen further up the Damoodah, as indicated upon the map; about half a mile beyond the last there is one of those large seams which are so characteristic of the Barákar group. It is probable that this was the principal seam visited by Mr. Williams, and from seeing which he formed an unfavorable opinion of the quality of the coal generally in this field. The details of this seam are here given in full, as they furnish an example of the manner in which a large quantity of coal occurs in a class of seams peculiar to the Barákar group.

Large characteristic seam.

Section, descending; dip 6° to N. 7° W.

	Ft.	In.
1. Sandstone	2	0
2. Sandy shales	3	10
3. Shales with streaks of *coal* ...	0	6
4. Shale slightly concretionary ...	1	0
5. *Coal*	0	6
6. Stony shale	0	5
Carried forward ...	8	3

	Brought forward ...	8	3	
7.	*Coal*	0	4	
8.	Coaly shale	0	5	
9.	*Coal*	0	2	
10.	Stony shale	1	0	
11.	*Coal*	0	8	
12.	Stony shale	0	4	
13.	Shale with streaks of *coal* ...	0	10	
14.	*Coal*	0	2	
15.	Stony shale	0	10	
16.	*Coal*	0	7	This portion might perhaps be worked profitably. The total thickness is six feet two inches, of which five feet one inch are *Coal*.
17.	Brown earthy *Coal*... ...	0	2	
18.	Coaly shale	0	5	
19.	*Coal*	1	2	
20.	Shale	0	1	
21.	*Coal* (inferior)	2	0	
22.	Shale	0	3	
23.	*Coal*	0	9	
24.	Stony shale	0	4	
25.	*Coal*	0	5	
26.	Stony shale	0	4	
27.	Coaly shale	0	8	
28.	Stony shale	0	6	
		20	8	

The remainder is much covered up, but appears to be of the same changeable character. The section was measured on the down-throw side of a small slip which traverses the seam. Close to this is the only trap dyke which occurs in the field; it is of very similar character to those found in the Ránigánj field.

Trap Dyke.

Some very fine plant stems (*calamites*) occur in the neighbouring sandstones; one measured five feet in length and was four inches broad. Before proceeding to speak of the geology further to the west it will be well to allude to the sections in the rivers which meet the Damoodah within that portion which we have just described.

Plants.

In the Hurdgudha river, east of the village of Gopo, two crushed seams are seen; the coal is of inferior quality. A little further down at the mouth of a small tributary there is a coal-seam about 12 feet thick, dip 8° S. W.

Hurdgudha Section.

		Ft.	In.
1.	Coaly shale	1	8
2.	*Coal*	0	4
3.	Coaly shale	1	2
4.	Carbonaceous shale	2	4
5.	Coaly shale	6	6
		12	0

Before the Hurdgudha meets the Damoodah two other seams, neither of any value, are exposed.

Bhera section.

We shall now proceed to examine the section afforded in the Bhera nuddee. This river meets the Damoodah about a mile from the village of Heshapoora. The junction of the two rivers forms a leading feature in a scene of singular beauty. The Damoodah has cut for itself a deep channel through the metamorphic rocks so as to exhibit an admirable section of the quartzites and micaceous and hornblendic schists which occur there: the softer varieties having been hollowed out still deeper retain the waters in a succession of pools which are connected by the stream. The banks are clothed with a luxuriant and dense jungle, and a picturesque Hindoo temple situated in the angle between the two rivers adds to the general effect, and testifies to its founder's appreciation of the beauties of nature.

Above the Talchír beds which occur, as we have already stated in the Bhera nuddee are thin-bedded sandstones and carbonaceous shales, followed by grits and sandstones containing runs of pebbles, after which we obtain the following section:—

				Ft.	In.
1.	Grit			18	0
2.	Sandstones, dip W. S. W. 12°			6	7
3.	Thick-bedded sandstones with bands of pebbles			40	0
4.	Coal seam				
	a Carbonaceous shale	1	0		
	b *Coal*	0	4		
	c Carbonaceous shale	1	6		
	d Coaly shale and inferior coal	2	0	4	10
5.	Sandstones with large pebbles			13	0
	Carried forward ...			82	5

		Ft.	In.
	Brought forward ...	82	5
6.	Run of ironstone, not continuous	0	8
7.	Sandstone	5	0
8.	Concretionary grey shales, carbonaceous in places	5	6
9.	Carbonaceous shale	9	0
10.	Sandstone—grit	4	6
11.	Carbonaceous shale with streaks of coal, dip 25°	3	6
12.	Concretionary grey shale	1	4
13.	Sandstone with bands of grit	15	0
14.	Carbonaceous shale and sandstones with carbonaceous streaks ...	1	3
15.	Grit	3	0
16.	Hard compact carbonaceous shale	2	6
17.	Grit	13	0
18.	Grey-sandy shales, carbonaceous towards the top, dip 35° ...	17	2
19.	Sandstones with runs of pebbles	15	0
20.	Grey sandy shales and bluish sandstones	8	0
21.	Blue argillaceous shales	1	1
22.	*Coal* seam—*Coal* with coaly shale	0	11
23.	Blue argillaceous shales	1	10
24.	Sandstone, falsely laminated and micaceous	2	10
25.	*Coal* seam, dip 20°		
	Carbonaceous shale 2 11		
	Coaly shale 6 6		
	Inferior *Coal* 2 8		
	Remainder of seam covered up 13 7	25	8
	Total	219	2

In this section the last seam alone contains coal which could be extracted profitably; the greater portion of it being covered by water, it is impossible to say what the total thickness of burnable coal may be. The dip 20° however is rather high for the present methods of working practised in Bengal. Some distance up the river we meet another seam of carbonaceous shale four feet thick; it is coaly towards the top. At the further end of the same reach in which this seam occurs are two seams, separated by a band of sandstone one foot thick. The lower one consists of two feet two inches of coaly shale; the upper one is obscured by fallen masses of sandstone, so that its thickness could not be determined.

We now return to the examination of the Damoodah and its tributaries west of the Poonoo Road ghat.

In the stream which runs close to the village of Simrabera is a seam, the dip of which is 25° to W. 10° S., the imperfect section as far as it is exposed is as follows:—

Simrabéra seam.

		Ft.	In.
a.	Carbonaceous shale		
b.	Inferior *coal*	0	6
c.	Coaly shale	0	10
d.	*Coal*	0	6
e.	Shale	0	5
f.	*Coal*	8	0
g.	Shale coaly in parts	4	6
h.	*Coal* covered up	?	

In the Khunder nuddee and a small stream branching from it, the following seams are exposed, the first, however, only very partially; its total thickness is not less than fifty-five feet, the coal appeared to be inferior. Higher up the stream are two seams measuring four feet and twenty-five feet with a dip of 30° to south-south east. Neither of these can be satisfactorily identified with any of the seams in the stream which cuts a section only a few hundred feet to the east. These last mentioned seams do not appear to contain much good coal, they are made up almost entirely of stony carbonaceous shale.

Khunder nuddee seams.

Trap.

A few fragments of rolled trap were observed lying in the bed of the stream, but none *in situ*.

In the Damoodah, between the mouths of the Khunder and Luganna nuddees, some beds of very Rániganj-like character are seen in section. Geologically, however, it is difficult to conceive how they could possibly belong to the upper group, so that, in spite of their lithological character, we have been obliged to regard them as Barákars. The occurrence of similarly circumstanced rocks in the Bokaro field furnishes further proof of the untrustworthy nature of lithological evidence alone, when applied to the distinction of the several groups forming the Damúda series.

Rániganj-like rocks.

At the point where the fault strikes the river, there is a much crushed seam of coal, thickness about one foot.

The next seams of any importance, disclosed by the Damoodah, are those occurring near the mouth of the Murumgudha nuddee. The bottom of the lowest of these is not seen, the details of the portion seen are—

(Dip 25° to S.S.W.)	Ft.	In.
Carbonaceous shale	5	2
Coal		4
Carbonaceous shale with bands of Coal	6	6
Coal good		5
Remainder not seen.		

This seam is on the north bank of the river. It is the only one in the field which has been cut into by the Natives, and that to a very small extent.

Other seams.

On the south bank of the river we find higher in the series the following seams, one containing four feet eight inches of tolerable coal; above it another in which there is at least one foot of inferior coal; these have the same dip as the one above mentioned. At the next bend of the river there is another seam, but its existence is only indicated by a blackening of the surface.

Iron-stone shales.

West of the mouth of the Murumgudha nuddee we come almost immediately upon the Iron-stone shales and above them the upper group of the Damúda series. Owing, however, to a cross-fault which has cut out these higher rocks, we find Barákars again occupying the bed of the Damoodah.

Seams crushed.

Various coal seams occur within this small area, some containing superior coal; but, owing to the crushing and contortions they have been subjected to, it is extremely improbable that any of them are in a workable condition. The largest of them is on the north boundary, and is cut obliquely by the fault; it contains some good coal, which, however, is in nearly vertical beds, strike 10° N. of E.

Seam near fault.

In immediate conjunction with the southern fault, and about half way between the temple at the Hazareebagh road ghat and the old fort, there are two, possibly three seams, but they are much crushed, and therefore, though containing fair coal, are of quite insignificant value.

Two seams occur near the mouth of the Nyeesurraie nuddee, the larger one is about 19 feet thick; it may be identical with the one mentioned as occurring on the north boundary. In the bed of the last-mentioned stream, there are two seams containing a small quantity of coal, but they also are much contorted.

Outliers.

Several small outliers of Barákars occur close to the boundary of this field; they are, however, of small size; their position is indicated upon the map.

Alteration of Barákars.

The alteration of some of the lower Talchír rocks has been alluded to. It not unfrequently happens that where the Barákars have overlapped, they too have been affected by the infiltration of silica.

Section II. IRON-STONE SHALE GROUP.—Differing from the group of Iron-stone and carbonaceous shales developed in the Rániganj field, its representative here has very little of the carbonaceous element. It consists exclusively of argillaceous shales and sandstones, with a few poor runs of argillaceous carbonate of iron.

Area.

Unconformity.

The area occupied by these rocks does not exceed half a square mile. The only section of them occurs in the Damoodah. At the base the dip is 70° to S. 10° W., this is quite unconformable to that of the nearest seen Barákars (25° to S. S. W.); however, as the absolute junction is covered up, and the vicinity of the faults may account for this apparent unconformity, it cannot be regarded as a safe indication of the relations of these groups. The alteration and fall in dip which accompanies the

junction between these rocks and those forming the Rániganj group is perhaps more clearly indicative of uneonformity, still the faults may have been the cause of this also.

Outlier.

A small outlier of Ironstone-shales occurs on the banks of the Damoodah about three miles south of Poonoo. On the occasion of my visit, a colony of Aguriahs was temporarily established close by for the purpose of making iron. Although coal, sufficiently good for the purpose was on the spot, and could be obtained with much less labour than is required in the preparation of charcoal, still they exclusively made use of the latter description of fuel.

Small pits are sunk into the shales north of Goburdaha, whence ore is taken out by the Aguriahs of the village of Kutha.

Section III. Rániganj group.—Brief as have been our remarks upon the Ironstone-shales, there is still less to be said about the rocks composing the Rániganj group.

Thickness uncertain.

The beds are so disturbed by faults that it is impossible to offer even an approximate estimate of their thickness. It is probably much less than half the full thickness seen in the Bokaro field.

Such rocks as are seen exhibit the usual lithological characters of the upper Damúda group.

No coal seams are exposed.

IV.—Superficial and recent deposits.

Extensive spreads of recent deposits such as are found in the district of Maunbhoom are rare in this part of Hazareebagh. Small patches of the following varieties have however been met with.

1 Clay Alluvium.
2 Sand.
3 Conglomerate.
4 Laterite.
5 Kunkur.

Alluvium.

Within the coal-field we do not anywhere find the rocks covered up by alluvium; but in several places the gneiss outside is entirely obscured by it. More especially is this the case on the south bank of the Damoodah south-east of the village of Sarum, and also south and south-west of the town of Ramgurh.

Sand.

Sand chiefly occurs in the long reaches of the river Damoodah outside the coal-field: occasionally it is found to extend some distance inland from the banks; when it forms slightly undulating ground clothed with several species of *carex* and grasses.

Conglomerates.

Conglomerates are found in several places in the bed of the Damoodah, one being on the south bank, north-east of the fort at Ramgurh, and another on the north bank, north-west of Lodhman. They consist of quartz and gneiss pebbles, bound up in a matrix which contains both iron and carbonate of lime.

Laterite.

Laterite occurs very sparingly indeed; two small patches outside the boundaries having alone been detected, one in the Damoodah, north-west of Burobing, and the other close to Kutha.

Kunkur.

Kunkur is very scarce outside, and does not occur inside, the field; close to the southern boundary of the Bokaro field, it is more abundant than elsewhere.

A saccharine limestone encrusting the rocks is seen in the bed of the Damoodah north of Kana, it is highly crystalline and exceedingly pure. Seen at a short distance it is suggestive of the appearance presented by drift snow.

In several streams thin crusts of carbonate of lime are found spreading over the gneiss and schistose rocks.

V.—Faults and dykes.

Three systems.

All the faults which have been discovered in the Ramgurh coal-field, with but one exception, seem to belong to one or other of three systems which correspond to those observed in the Ráníganj field.

I. East and West faults.

The principal fault belonging to this system in the Ramgurh field is that which forms the southern boundary. Tracing along this boundary from east to west, we find no sign of a fault until we reach the Damoodah close to the Poonoo road; the rocks seen there on either side of the river indicate that a certain amount of shifting has taken place, the line of fault being identical with the central channel of the river. At this point the fault seems to have exercised its minimum action; as we go further west, with each step we find higher and higher beds thrown down. Antecedent to this fault occurred the one which strikes N. by W.: the effect of this was to throw down the upper Damudás and Ironstones on the east, and thus to bring them within the influence of the former. But for this we should probably have no trace of these beds remaining. To this system may also be referred the fault which lies a short distance to the north of Ramgurh. It is a somewhat interesting feature of this one that where it ceases to form a boundary and runs into the sedimentary rocks it has been considerably deflected from its original direction. It is marked very distinctly by a strong ridge of fault-rock which in some places is from 50 to 60 feet wide.

II. North and South, or slightly East of North and West of South faults.

An example of this system is the fault forming a portion of the Eastern boundary and cutting off patches of both Barákars and Talchírs. Relatively to the others, there are no data for determining the age of this system.

III. North-North-West and South-South-East faults.

The pair of faults which have thrown the Barákars south of Soogea are examples of this system. Its period was subsequent to that of No. I.

Fault Rock.—Without any exeeption the faults of this area whether in the sedimentary or metamorphic rocks are, at least in portions of their extent, accompanied by fault-rock.

This rock is divisible into three principal varieties;

1. Pseudomorphic quartz.
2. Brecciated quartz.
3. Hornstone.

Pseudomorphic quartz. The most abundant form of this variety of fault-rock consists of a series of porcelanic-looking plates; these are strongly suggestive of the well known crystals exhibited by Barytes. Some of the specimens contained traces of micaceous iron ore between the plates. As these two minerals not uncommonly occur in nature together, it seems all the more probable that Barytes was the original mineral which has been replaced by silica. The faces of these plates frequently exhibit peculiar striations which cut one another diagonally and so form series of triangles. The other form resembles closely the ordinary fibrous variety of Gypsum and sometimes that of Celestine; there can be little question that these were the minerals which have been replaced by silica.

The pseudomorphic variety is best seen in the runs of fault-rock which are marked on the maps in the vicinity of Oorlah and Koojoo. It is also seen in the fault which runs into the field north of the Damoodah at Ramgurh, and in the fault at the other side of the field in the neighbourhood of Ticahara. The hills at Kurma have axes formed of the same rock. In the northern one it forms a sharp ridge which along the immediate line of summit is often only a few feet wide.

Brecciated quartz. This form is not abundant. It consists simply of angular fragments of quartz in a siliceous, sometimes slightly felspathic matrix.

Hornstone. In the commonest form this is simply a compact siliceous rock not exhibiting any trace of subsidiary structure, as for example, in the fault-rock close to the temple at Ramgurh ghat. Sometimes by the addition of felspar, this rock becomes a pegmatite, and in one locality near Ticahara it gradually changes into a granite.

Dykes.

Within the area of the coal-field only one trap dyke is exposed. It crosses the Damoodah north-east of Burobing; it is a good deal decomposed and has an earthy appearance similar to that of many of those seen in the Rániganj field.

Greenstone.

In the neighbourhood of the field there are several greenstone dykes, as indicated upon the map: they are of no great importance as the longest of them can only be traced for a few hundred feet.

Basalt.

One remarkably compact basalt dyke occurs in the Hurdgudha nuddee east of Gopo; it is only traceable for a few yards.

Trachyte.

Near the village of Gopo there is a small hill formed of trachyte. The rock is composed almost entirely of felspar, and is in parts very vesicular.

VI.—Economic Summay.

It will already have been gathered from what has gone before that this field is of but small value in an economic point of view.

Coal in the east.

The coal in the eastern part of the field occurs generally in thick seams, some of them having low dips; but the quality is so variable, thin bands of coal frequently alternating with stony carbonaceous shale, that it is improbable that the

former, even under the most favorable conditions of market and carriage, could ever be extracted with profit.

Coal in the west.

In the western extension of the field where the coal is not only of a workable thickness, but also of much better quality, the high dip and the cutting off and crushing up of the seams by faults cause them to be even less likely to produce a profitable out-turn of coal.

It does not seem probable therefore that the Ramgurh coal field will ever be worked to any great extent.

Iron ore.

The usual carbonaceous ore of iron is found in the ironstone shales; it is, however, of an inferior quality, and its abundance is below the average found in other fields.

VII.—Crystalline Rocks.

In the course of the examination of the Ramgurh Coal-field, occasion was taken to visit and note upon the characters of the surrounding crystalline rocks. The general results of this cursory survey will be briefly indicated here.

Igneous rocks.

Within the area which has been thus visited (the limits of which may be best understood by a reference to the accompanying map), no true igneous rocks, with the exception of the traps already mentioned, have been observed.

Granite.

Granites and granitic syenites, which in hand specimens are lithologically undistinguishable from ordinary intrusive igneous rocks, occur abundantly. Examination in the field has, however, tended to show that in every instance these are referable to one or other of the following sub-divisions:—

Three varieties.

a. The first and most abundant variety is simply an unfoliated gneiss; it occurs regularly interbedded with the foliated gneiss and schists, but is lithologically undistinguishable from a true granite; we shall allude to it again when speaking of the metamorphic series generally.

b. Interbedded with the gneiss, we occasionally find another granitic rock which is distinguished from the ordinary metamorphic granite by being accompanied by a certain amount of local alteration and contortion. Its strike is generally, if not always, coincident with that of the adjoining metamorphic rocks; this feature separates it from true igneous granite, which, although not met with in the area at present under consideration, is found in several parts of the adjoining district of Maunbhoom, where it cuts across, and is quite independent of the strike of the surrounding rocks.

The peculiar characters of this rock are probably due to the fact that in age it was contemporaneous with the metamorphism, and that it was either the metamorphosing agent itself or was directly connected with it, and was thrust up and injected between the pre-existing beds, which were then undergoing the process of alteration.

The texture of this granite exhibits every degree of coarseness, and is in no respect lithologically distinct from the other varieties; in addition to the ordinary minerals, quartz, orthoclase (two varieties), and mica (two varieties), it also contains hornblende and epidote, and less frequently tourmaline and garnets.

To this sub-division the *protogine* granite which is found in several parts of the area seems to belong; it consists of quartz, pink orthoclase, and a green mineral allied to serpentine.

c. The third variety traverses the gneiss and associated rocks in directions which correspond to those of the principal joints or their conjugates. It also occurs in places where there appears to have been local crushing-up or contortion.

As to what the origin of this variety may be, two alternatives present themselves. On the one hand, it may be what is commonly described as vein granite, and, on the other, its origin may resemble that

of metallic lodes. With regard to a large proportion of it, the latter seems, for the following reasons, to be the more correct view :—

First.—It does not seem to have affected the neighbouring rocks as we should expect it to have done had it been intruded in a molten condition.

Secondly.—In some of the *lodes*, the formation of the granite seems to have been from some cause arrested, and we find that the deposition having commenced on the walls of the joints, proceeded thence to the centre, but that the source of the granite minerals was cut off before the opposing faces succeeded in meeting.

The regular metamorphic series is represented in this area by several varieties of gneiss, &c.; the succession in ascending order being approximately as follows :—

Porphyrytic gneiss.
Granitic "
Syenitic "
Felspathic "
Quartzites. } Alternating with one another.
Mica-schists. }
Actinolite and hornblendic schists. }
Sandstone like gneiss.
Hornblendic schists.

Dip.

The dip of these rocks varies very much, being sometimes as low as 20°, but more frequently it is close upon the vertical; the prevailing direction is due north in the southern portion of the area, but in the vicinity of the Bokaro Coal-field, it bends round towards the east.

Porphyrytic gneiss.

Composition.

The lowest of these rocks, the porphyrytic gneiss, is the most interesting member of the series, whether we regard it from a lithological or a geological point of view. It is composed of mica (two species), quartz and orthoclase felspar, the latter occurring both in the general matrix and in peculiar twin crystals which in section form

an obtuse ellipse. They sometimes occur so abundantly and with so little common direction of their axes as to give the rock the appearance of a conglomerate.

Physical characters.

The chief physical character which distinguishes this rock is its tendency to form bosses and tors; the former exhibit a perfectly smooth and dome-like outline, which at first one is apt to suppose must be due to glacial action; closer examination, however, proves it to be a structure penetrating far beneath the surface, and, in fact, that the bosses are not solid masses of rock, but consist of a series of concentric shells, the thickness of which varies from eight inches up to two feet. Different bosses exhibit various stages of the break-up of these shells; some have a curved fragment clinging on here and there, while others exhibit a perfectly smooth unbroken surface; a talus at the base being the only remains left of the last shell.

Theories.

No theory yet put forward has satisfactorily accounted for the origin of these shells, or rather we should say of the spherical joints which have given rise to them. It has been suggested that heavy showers of rain falling on the surface of the rock which had become heated by the sun have produced a sudden contraction and consequent splitting off of the shells; this explanation, however, is obviously insufficient to account for any but the very thinnest layers; the non-conducting powers of stone rendering it quite impossible that the sun's heat could penetrate to a depth of two feet.

Probable explanation.

The true explanation will probably be found to be that this structure was formed as the rock cooled down from the high temperature to which it may have been raised during the process of metamorphism. The fact of a somewhat similar structure being occasionally seen in igneous granites and lavas favors the idea that it is due to internal heat.

These bosses occur most abundantly south of the Ramgurh field; as we approach the south boundary of that field, we find the porphyrytic gneiss is overlaid by the granitic and syenitic varieties; these also occasionally form bosses, in which, however, the *shell* structure is not so well developed.

Position of bosses.

Above these last are found quartzites, felspathic gneiss, and mica-schists, alternating with hornblendic schists. The quartzites are less frequently met with than the other varieties. They seldom consist of pure silica; more frequently containing either a small proportion of felspar or a few scattered crystals of mica.

Other rocks.

The mica-schists, too, occur but seldom in the sections. Near the village of Bulsugra, west of the Bokaro field, they seemed to be more strongly developed than elsewhere.

Mica-schists.

The hornblendic schists display their ordinary characters, *i. e.*, some are distinctly foliated, while others are compact and often undistinguishable from greenstone; while still another variety, owing to the absence of foliation and the distinct crystallisation of the component minerals, might easily be mistaken for a diorite.

Hornblendic schists.

Towards the south boundary of the Bokaro field occur a number of north and south ridges of sandstone-like gneiss and hornblendic schists. The former, when slightly disintegrated, is not easily distinguishable from an ordinary coal-measure sandstone. The latter correspond to the varieties of hornblendic schists already mentioned; the chief difference being that the cannon-ball structure is better developed, or perhaps it may be only more favorably exposed.

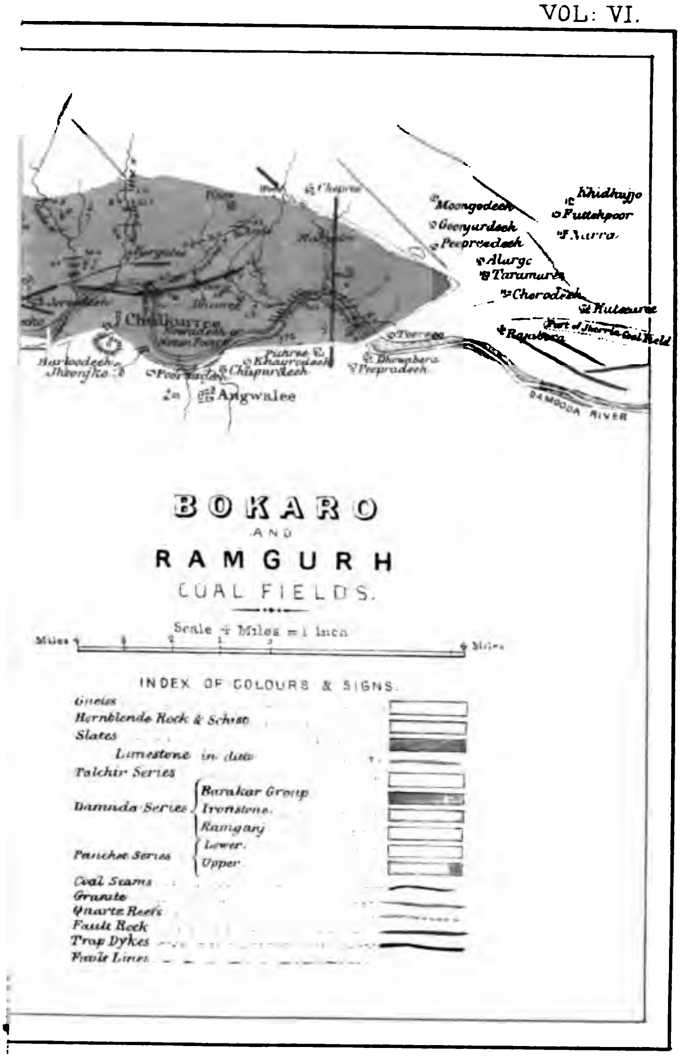
Sandstone-like gneiss.

Conglomerates.

Metamorphic conglomerates were met with in the stream south of Heshapoora, and near the village of Soogea. The matrix had a gneissose structure, and contained rounded quartz pebbles of various sizes.

Argillaceous slates.

West of this area some argillaceous slates form the hills, upon the flanks of which the sandstones of the Chengurhra (or south Karunpoora) coal-field rest; nothing about the relation which they bear to the gneiss is yet known, so we are obliged to pass them over for the present with this brief notice.


Chapree
Moongodeeh
Futtehpoor
Narra
Tarumuree
Cherodeeh
Part of Jherria Coal Field
Pichree
Khaurodeeh
Chupurdeeh
Angwalee
Dhowbara
Peepradeeh
DAMOODA RIVER
BOKARO
AND
RAMGURH
COAL FIELDS.
Scale 4 Miles = 1 Inch
Miles
INDEX OF COLOURS & SIGNS.
Gneiss
Hornblende Rock & Schist
Slates
Limestone in ditto
Talchir Series
Damuda Series
Barakar Group
Ironstone
Ramgarh
Panchet Series
Lower
Upper
Coal Seams
Granite
Quartz Reefs
Fault Rock
Trap Dykes
Fault Lines

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the TRAPS *and* INTERTRAPPEAN BEDS *of* WESTERN *and* CENTRAL INDIA, *by*
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CONTENTS.

1. *Introduction.*—During the five years which have now elapsed since the Geological Survey of India was extended to the Bombay Presidency, a very considerable portion of the immense tract occupied by volcanic rocks in Western and Central India has been examined, more or less closely. Nearly the whole valley of the Taptee and its tributaries, the Nerbuddda valley west of Hoshungabad, and a considerable tract of country around Nagpoor, have been surveyed; whilst rapid traverses of the country between Bombay and Nagpoor have been made, and the neighbourhoods of Bombay, Poona, Ahmednuggur, Jaulna, Mahableshwar, Baitool, Chindwarra, and Rajamundry, together with portions of Sind and of Cutch, have been more or less closely examined.

Until however still more extensive areas of this widely spread series of rocks have been surveyed, no complete general account of them can

be given; still the observations made in the course of the survey have added to our knowledge of them, despite the excellent previous descriptions of Dangerfield*, Sykes†, Malcolmson‡, Newbold§, Carter||, Hislop¶, J. G. Medlicott**, and others, and these additions comprise points connected with both the physical character of the rocks and their geological age.

The previous explorers to whom I have referred have well described the most striking features of the extraordinary tract of country occupied by the traps. The vast area covered by the volcanic formations, the enormous accumulation of horizontal or nearly horizontal beds of basaltic rock, the distinct stratification, the massive flat topped hills which are the result of these characters, the precipitous scarps, (the origin of which however has generally, I think, been incorrectly attributed to other causes than the real one, aqueous denudation,) the absence of craters, the abundance of zeolites and other minerals, and the presence, locally, of interstratified beds, calcareous or siliceous, containing freshwater fossils, have all been noted again and again. I shall therefore attempt no general description of the volcanic area, but pass on to the consideration of some of its principal characters.

2. *Area covered by traps.*—First, as regards extent, the traps stretch uninterruptedly from near Belgaum (lat. 15° 5′0 N.) to Goona (lat. 24° 30′ N.), and from Bombay (long. 72° 50′ E.) to Umurkuntuk (long. 81° 50′ E.). This is, however, by no means the whole of their

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* Sir J. Malcolm, Memoir of Central India, Vol. II, p. 313, 1823.

† Geological Transactions, Ser. 2, Vol. IV., p. 409, 1833.

‡ Id. Vol. V, p. 537, 1837.

§ Jour. Roy. As. Soc., London, Vol. IX, p. 20, 1848.

|| Jour. of the Bombay Br. Roy. As. Soc., Vol. V, p. 255, &c. 1853.

¶ Quar. Jour. Geol. Soc. of London, Vol. XI, p. 356, 1854.

** Memoirs Geol. Surv. India, Vol. II, p. 217, 1860.

original extent. Outliers are represented for nearly a degree south of Belgaum upon Malcolmson's map*, but as regards the extreme original extension, both north and south, additional information is still required. Of their extension to the east also something has yet to be learned; some interesting observations have been made within the last year by my fellow surveyors; Mr. H. B. Medlicott met with an outlier in Sirgoojah District on the hills west of Burwa, well east of the parallel of 84°; and still further east, caps of trap have been found by various officers of the survey upon some of the hills which intervene between Sirgoojah and the Rajmahal hills in Bengal, but it is not yet ascertained whether these should be referred to the jurassic† traps of Rajmahal, or to the Deccan and Malwa series, which, as I shall show presently, are not of older age than middle cretaceous.

Several writers have suggested‡ that the traps and their interstratified sedimentary formations with marine fossils which occur in the neighbourhood of Rajamundry belong to the same great series as the basaltic rocks of the Deccan; and amongst the fossils obtained at Rajamundry by Lieutenant Stoddart, and described by the late Mr. Hislop§, were specimens of freshwater species identical with those found in intertrappean beds in Central India. Since this paper was first written I have had an opportunity of examining the beds at Kateru, close to Rajamundry, and I find that the trap is precisely similar in mineral character to one of the commonest varieties occurring in the Deccan. I did not succeed in finding any specimens of *Physa Prinsepii*, or of the other

* Geol. Trans. Ser. 2, Vol. V, Pl. XLVI.

† See paper on Cutch ante, this vol., pp. (32), (38).

‡ The first, I think, was Newbold, in Jour. As. Soc. of Bengal, Vol. XI, p. 957, Note. The first notice of the occurrence o ffossils near Rajamundry was by Dr. Benza, in Mad. Jour. Lit. and Sci., Vol. V, p. 50-53, and Jour. As. Soc. Bengal, Vol. IV, p. 435.

§ Quar. Jour. Geol. Soc., Vol. XVI, p. 154.

species of freshwater shells mentioned by Mr. Hislop, as obtained by him from Rajamundry, but I met with a well preserved specimen which I have little hesitation in referring to, *Lymnea subulata*. Sow, a shell as characteristic of the Central India intertrappeans as *Physa Prinsepii* is. I can therefore to some extent confirm Mr. Hislop's deductions as to the existence of traps belonging to the Deccan series at Rajamundry, but I do not think it is yet satisfactorily shown that these rocks ever extended across the intervening area, although I by no means think such a former extension improbable. Outliers are represented on Malcolmson's map, already referred to, as dotted over much of the intermediate country, but of these, one of the largest is represented as stretching for a considerable distance along the Godavery at Bhadrachellum, which town appears in the map to stand upon the outlier. In a recent journey down the Godavery, which, however, was too hurried to allow me to search to any extent, I did not observe any of these outliers, and at Bhadrachellum all the rocks appeared to be metamorphic; but my means of observing were far from sufficient to enable me to state that trap does not occur in the neighbourhood of the river. Other outliers of basalt appear marked on the same map near Ongole, 150 miles south-west of Rajamundry, and about the same distance south-east of Hyderabad. I do not know to what formation these belong.

Some observers have considered the trap dykes which occur in metamorphic and other rocks throughout India evidence of the former extension of the Deccan trap. This, however, is an error, as has been shown by Newbold and others, there being abundant evidence that these dykes are, in many instances, of far greater antiquity.

To the west I can add something more positive as to the extension of the trap area. I have shown in a previous paper* in this volume that

* See ante, p. (21).

the basaltic rocks of Cutch* unmistakably belong to the Deccan trap series. This carries the western boundary as far west as longitude 69.° The beds in Cutch are about 2,000 feet thick. I have also discussed the possibility of the small section of amygdaloidal basalt which occurs at the base of the nummulitic rocks at Runneekote† in Sind belonging to the same series, and have pointed out the possible connection of some of the volcanic rocks found on the coast of Arabia by Dr. Carter.

Independently of Sind, we have thus good evidence of the extension of these volcanic rocks *throughout* 9½ *degrees of latitude and* 15 *of longitude.* The area covered by them in the Peninsula of India can be little less than 200,000 square miles.

3.—*Petrology.*—Next, as regards mineral character. The most striking peculiarity is the great prevalence of amygdaloid, in which the kernels, containing chiefly zeolite or agate, sometimes form the principal part of the rock. The most common zeolitic mineral occurring is *Stilbite,* next in abundance are *Apophyllite, Heulandite, Laumonite,* and *Mesotype* or *Natrolite*‡. *Chabasite* and *Thomsonite* are rare. *Analcime,* which is said to occur by some writers, I have never met with.

Usually the nodules, both of zeolite and of agate, (the two frequently, though not always, being found in distinct beds of trap,) are surrounded by a layer of green earth, the great prevalence of which mineral is extremely characteristic.

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* See Captain Grant's map; Geol. Trans. Ser. 2, Vol. V, pl. XLVI.

† See ante, p. (5).

‡ The Rev. Professor Haughton's species *Hislopite* (Phil. Mag. 1859, Vol. XVII, p. 16) is evidently merely *Calcite,* coloured by green earth, and, of course, no more a mineral species than Fontainebleau sandstone is. See also Dr. Carter's note to a paper by Mr. Hislop in Jour. Bombay Br. Roy. As. Soc., Vol. VI, p. 194. It remains to be seen whether the *Syhedrite* of Professor Shepard, American Journal of Science for July, 1865, Vol. XL, p. 110, is not *Stilbite,* coloured in the same manner. In any case the name ought to be *Syhadrite* from the Syhadri, the range known in English by the absurd title of the Western Ghâts.

Another equally characteristic rock, though less abundant, is a peculiar porphyritic basalt, containing numerous tabular crystals of glassy felspar, often greenish in colour, and measuring usually from ½ inch to 2 inches across.

Both these forms of rock have been pointed out by other observers, and especially by Dr. Carter and Colonel Sykes, but they are so peculiarly characteristic of the Deccan traps that they will bear referring to again. It was by means of their occurrence that I was enabled to recognise immediately the traps of Cutch as belonging to the same series as that of the Deccan and Malwa.

4. *Occurrence of volcanic ash.*—There is one peculiarity of this series, however, which has not been before, I think, clearly pointed out, and that is the frequent occurrence throughout of beds of volcanic ash. The beds have, it is true, been noticed and well described by Malcolmson* and Carter†, under the name of basaltic breccia, or volcanic breccia, but both these writers looked upon the rock as intrusive. This, I feel convinced, is an error; the rocks in question are so precisely similar to those formed of the ejecta showered forth from volcanoes during eruption, and which constitute the greater portion of the cone of most large recent and extinct volcanoes, that I have no hesitation in considering them as identical.

In some places, no inconsiderable proportion of the whole series is formed of this rock. Several beds may be seen in the cuttings upon the sides of the hill ranges traversed by the road between Poona and Mahableshwar, especially at the Kamatki Ghat. One bed is peculiarly

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* Trans. Geol. Soc., Bombay, Vol. VI, p. 372, note.

† Geology of the Island of Bombay, Jour. Bombay Br. Roy. As. Soc., Vol. IV, pp. 164, 195. Summary of the Geology of India, id. Vol. V, p. 287. See also Vol. VI, p. 171, &c

conspicuous at the lower gateway leading to the fortress of Singurh near Poona.* A little occurs in the Island of Bombay, and there is a well marked bed on the Island of Slasette in which the Buddhist caves of Kanheri are cut. But the rock occurs almost everywhere, and may be easily recognised by its irregular weathering, the scoriaceous blocks remaining in relief upon the surface precisely as in old volcanic cones. Very frequently a thin bed of ash occurs between different trap flows, and this sometimes passes into the red clay or bole so commonly interstratified with the traps, and which, also, I am rather disposed to look upon as a form of volcanic ash. Mr. Hislop considers this bole as sedimentary.† He may perhaps be right, but I have never seen either pebbles or organic remains in it, and, as before said, it is distinctly mixed at times with the scoriaceous breccia. This does not, however, prove the bole not to have had a sedimentary origin, as the volcanic scoriæ might have been showered into water as well as on land.

5. *Horizontality of traps. Thickness of beds.*—One of the most remarkable characters of the traps is their surprising horizontality. This is very conspicuous along the Syhadri range east of Bombay, in the scarp south of Khandeish, throughout the vast tract of country between Poona and Nagpoor, (about 400 miles,) and on the scarp of the Malwa plateau, north of the Nerbudda. Where exceptions occur, the dips are almost certainly due to subsequent disturbance, as along the coast at Bombay and to the northward, in the Sathpoora and Rajpipla hills, and on the lower Nerbudda. In most of these cases the disturbance is proved to be of later date than that of the deposition of the traps by its affecting contemporaneous or later beds of sedimentary

* This was noticed by Malcolmson.

† Quar. Jour., Geol. Soc., Vol. XI, p. 364.

origin, such as the intertrappean "frog beds" of Bombay, and the nummulitics of the Rajpipla hills. The only departure from absolute horizontality to be seen in the traps of the Deccan is frequently no more than may be due to the lenticular form of the beds. Yet the separate lava flows are of no great thickness, the average in two sections which I measured, upon the railway on the Bhore and Thull Ghats, was apparently 64 and 87 feet respectively, but really less, for the distinction between the beds could, in most cases, only be distinguished by lithological characters; and when, as must frequently have been the case, two or more beds of similar appearance and composition occurred together, they were frequently measured as one. Indeed many of the more amygdaloidal flows appeared to be made up of smaller flows from 6 to 10 feet thick, distinguished by being highly amygdaloidal above, less so in the middle, and marked towards the base with long sub-cylindrical vertical pipes, of small diameter, filled with zeolite; the more amygdaloidal character of the upper part of each stratum being apparently due to its having been originally more vesicular near its surface. But even supposing that these apparent distinctions are accidental, some distinct crystalline flows in both sections do not exceed 15 feet, and even assuming the average to be that given above, it is evident that the lava must have been poured out in a very liquid state to have spread so evenly over a surface so nearly horizontal. I think it worthy of consideration whether some of the beds, especially the more earthy ones, may not have been volcanic muds, and not true lavas.

6. *Volcanic foci.*—The absence of distinct volcanic foci has often been noticed. Of course cones of loose scoriæ would be too easily removed by denudation to be left, and if the nuclei of the volcanoes were of basalt (and they probably were so) similar in character to some of the lava flows, it would be extremely difficult to recognise them. Still it is curious that so few should have been met with. I have, I think, seen one or two

volcanic nuclei on the lower Nerbudda, and several in Cutch,* but over the Deccan area, it is difficult to conceive where the centres of eruption can have been situated. In the Rajpipla hills, between the Taptee and Nerbudda, the numerous large dykes, and the disturbance which the traps have undergone, are evidences of a great centre of volcanic energy, and there may be other similar foci elsewhere, but I am unacquainted with them. The paucity of dykes in the Deccan is remarkable. Still they do occur and were noted by Sykes. The almost universal distribution of volcanic ash containing large angular blocks apparently showered out from volcanoes, and which cannot have accumulated far from actual vents, proves that these vents must have existed throughout the country; but it is very remarkable that in no single instance have the *inclined* beds of any cone been found preserved, enveloped by subsequent horizontal flows.

7. *The Deccan and Malwa traps not of sub-marine origin.*—It appears to have been a favorite idea with many geologists that the Deccan and Malwa traps were originally deposited beneath the sea. In favor of this hypothesis I can find no evidence whatever. Mr. Hislop has shown reasons for objecting to it,† and I should not have referred to it here had it not been supported by Captain Newbold,‡ who is, in many respects, the best informed and most logical of all the earlier Indian geologists. His arguments are—

1st.—The absence of cones and craters of elevation:

2nd.—Its (the trap's) usual compact structure:

3rd.—The want of conformity of the trap to the lowest level of existing valleys:

4th.—The occasional intercalation of marine beds.

* The so-called volcano of Denodur I believe to be one.

† Quar. Jour. Geol. Soc., Vol. XI, p. 368.

‡ Jour. Roy. As. Soc., Vol. IX, p. 42.

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1st.—The enormous amount of denudation which has taken place since the trappean epoch, and which has swept away upwards of 2,000 feet of solid rock from the surface of the great Deccan plateau, would have removed all trace of volcanic cones, if such had existed, as has been shown by Carter and others.

2nd.—This argument, I think, rests upon a fallacy: many sub-aerial lavas are as compact as any other igneous rocks. But if any peculiarity, more than another, is characteristic of the Deccan and Malwa traps, it is their excessively vesicular nature. That the rocks are not now vesicular is true, the hollows have been filled by silica, or by various species of zeolites. But if the spaces, now filled by quartz, agate, or zeolite, were not originally air bubbles, what were they? Neither quartz, agate nor zeolite could have existed as such in lava, whether sub-aerial or sub-marine; the water chemically combined with the zeolites would have been expelled, and the chemical constituents of all have been fused and combined with the mass of the rock. Finally, is it certain that sub-marine lavas are not vesicular? My own impression is that, although the superincumbent pressure might diminish the size of the gas bubbles to some slight degree, it could have no further effect, and I cannot see why gas (usually water vapour) bubbles should necessarily be absent beneath the sea.

3rd.—I do not clearly understand the force of this argument. I cannot see in what way the relation of the planes of bedding in the traps to the bottoms of recent valleys proves more than that the present surface is not identical with that which existed in pre-trappean times, which is a matter of course. Probably Captain Newbold means something else, but he has expressed himself ill, and I can only confess my inability to follow his argument.

4th.—The only spot in which marine organisms have been found associated with the traps is close to Rajamundry, and their occurrence

there may be taken as evidence that the lowest traps with which they are intercalated, were poured out, not on the bed of the ocean, but on the sea shore, or in an estuary; many of the shells met with being clearly estuarine forms, and the association of freshwater species being evidence of the presence of land.* With this exception, the only sedimentary beds which occur interstratified with the traps from Umurkuntuk to Bombay, and from Gwalior to Belgaum, are distinctly freshwater, and, in most instances, lacustrine, no marine organism whatever having as yet been met with in them. With regard to the great mass of the trappean formations, in which sedimentary strata are absent, this very absence of detrital deposits is strong proof of the subaerial accumulation of the lava flows. It is also, I think, inconceivable that lava flows beneath water could have preserved their liquidity sufficiently to be spread out in the thin and enormously extended horizontal beds of which the traps are in great measure composed; they must necessarily, it appears to me, have cooled more rapidly than in the air.

8. *Duration of volcanic period.*—Those who have fully appreciated the gradual conviction which has of late years been forced upon the minds of most field geologists, of the enormous periods of time which have been necessary for the accumulation of the various rock masses forming the earth's crust, will have no difficulty in understanding that a large division, even of geological time, may very probably have elapsed during the accumulation of the Deccan traps. The thickness of these beds cannot be much less than 5,000 feet, perhaps it is considerably more. Upwards of 4,000 feet are seen in the precipitous sides of the valleys below Mahableshwar. Probably considerably more than this is exposed in the Island of Salsette and the neighbouring mainland, but the thickness of the section there exposed has not been accurately

* Quar. Jour. Geol. Soc., Vol. XVI, pp. 176-182.

measured. Yet that long intervals of time, in some cases, at least, elapsed between the different lava flows of which this immense thickness is composed, is shown by the local accumulation of freshwater deposits abounding in remains of animals and plants.* In each of these cases a lake must have been formed, and have become tenanted by a large number of different species of mollusca, &c., a very slow process. In some places, near Baroda, I met with large accumulations of rounded pebbles, not only of metamorphic and sedimentary rocks, but of the trap itself, intercalated between beds of basalt and amygdaloid, so that denudation must have taken place to a considerable extent in the intervals between successive flows.† These accumulations appeared to have been deposited in hollows excavated in the underlying trap beds, and as currents of water must have been necessary to move such pebbles and to round them, it is only reasonable to conclude that these hollows were river beds, cut into the surface of the consolidated trap flows, and refilled by gravel and detritus, all in the interval between successive eruptions. It should, however, be added that these signs of long intervals are confined, so far as I have as yet observed them, to traps very low down in the series.

9.—*Intertrappean beds.*—I have already had occasion to advert to the sedimentary beds intercalated with the traps. These have been described by various writers, but especially by Dr. Malcolmson‡, Dr. Carter§, Mr. Hislop‖, and Mr. J. G. Medlicott¶. The first described

* I shall show presently that these were accumulated in intervals between trap flows, and not, as held by Mr. Hisolp and Dr. Carter, previously to the commencement of the volcanic outbursts.

† This has been observed by Mr. J. G. Medlicott also; Memoirs of Geological Survey of India, Vol. II, p. 208.

‡ Geol. Trans., Ser. 2, Vol. V, p. 549, &c.

§ Jour. Bombay Br. Roy. As. Soc., Vol. IV, p. 174, &c.

‖ Quar. Jour. Geol. Soc., Vol. XI, p. 356, and Vol. XVI, p. 154.

¶ Memoirs Geol. Surv. Ind., Vol. II, p. 199.

the deposits of Berar and the Nizam's territories, the second those of Bombay Island, the third those of the neighbourhood of Nagpoor, and the fourth those of the Nerbudda Valley. Dr. Carter and Mr. Hislop agree generally in their views of the mode in which these rocks have been formed; Mr. Medlicott, with whom I entirely agree, differs from them. Dr. Malcolmson did not enter into theoretical speculations.

The rocks of the Island of Bombay have recently been re-described by my colleague Mr. Wynne,* who has shown that the views originally held by Mr. Clark, Dr. Buist, and others of the interstratification of the sedimentary rocks with the trap beds agree far better with the facts than Dr. Carter's very ingenious, but somewhat complicated hypothesis of the deposition of the freshwater beds in the first place, and of their subsequent disruption by successive volcanic outbursts. I entirely coincide with Mr. Wynne's opinions in this matter. I think there can be no question that the rocks of Bombay consist of a number of successive flows of lava differing in mineral composition, and that sedimentary beds were deposited, probably in lakes, upon several different flows in succession.

The majority of the fossils described by Dr. Carter from the Bombay intertrappean formation were obtained from the sedimentary bed which underlies the basalt of Malabar hill, the thickest bed known to be intercalated with the traps anywhere. The most important fossils are Amphibian or Reptilian; they include a frog (*Rana pusilla*, Owen) closely allied to existing species, and a tortoise, besides entomostraca, insects, some obscure remains of mollusca, and plants.

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* Memoirs Geol. Surv. Ind., Vol. V, Art 3.

10.—*Distinctions between intertrappeans of Bombay and those of Central India.*—It is worthy of remark that this fauna (the plants are but ill preserved*) comprises but one species (*Cypris cylindrica,* Sow.) found in the intertrappean beds of Central India, although the latter, throughout an immense tract of country, the extremes of which are further from each other than some of them are from Bombay, contain a remarkably persistent fauna, mainly molluscan. The exception is a species which is said to have survived to the present day, and is therefore worthless as an indication of geological age. Both formations have, however, been generally assumed to be identical, and although Dr. Carter once† suggested that the Central Indian beds were older, his views were founded on a supposition that the traps of Bombay belong to a distinct series to those of the Deccan,‡ which is not correct, and on the fossil condition of the shells in the Nagpoor intertrappeans being different from that of land and freshwater shells in the European eocene, scarcely an admissible argument.

The truth is, (and, so far as I am aware, it has not been clearly pointed out before,) that the Bombay strata, although a part of the same series as the traps of the Deccan, are the highest beds of the traps exposed, higher probably even than those of Mahableshwar, while the Nerbudda, Nagpoor, and Berar intertrappeans, wherever I have met with them, are never more than 200 or 300 feet above the base of the

* They are, however, considered by Mr. Hislop distinct from those found in the intertrappean beds near Nagpoor. Quar. Jour. Geol. Soc., Vol. XI, p. 365.

† Geological papers on Western India, p. 744.

‡ Dr. Carter considered the Bombay traps as belonging to a more recent series than those of the Deccan. I can find no evidence in favor of this view; but as I have already remarked, I am compelled to dissent entirely from Dr. Carter's views on the mode of eruption of the Bombay traps.

series, so that they are intercalated with traps probably 4,000 or 5,000 feet lower than those of Bombay. The accompanying sketch section will illustrate this. East of Bombay for several miles (about 10 or 12) the traps dip steadily at from 5° to 10° to the west, so that higher and higher beds are constantly exposed to the westward, and the highest are those seen in the Islands of Bombay and Salsette. It should be remembered that the lowest beds seen in the Konkan, east of Bombay, viz., the horizontal beds which stretch away from near Kallian, where the western dip commences, to Matheran hill and thence to the foot of the ghats, are not necessarily the lowest beds of the trap, as their base is not seen. True, the Nagpoor and Berar beds are not necessarily the oldest beds either, for we have no proof that the basement beds of the trap are everywhere of the same age, or what is the same, that volcanic outbursts commenced at the same time over all the area covered by them.* All that is proved is, that the Nagpoor intertrappeans are associated with the lowest traps seen near Nagpoor, and the Bombay intertrappeans with the highest seen near Bombay, and as both belong to one series, it is fair to

Sketch Section from Bombay Island to Matheran; about 30 miles. The Western Ghâts are of the same height as Matheran, and evidently a continuation of the same beds.

* That they are, however, approximately of the same age throughout a large portion of their range appears probable from their resting on the bagh beds and their equivalents with only slight unconformity, and from the intercalated sedimentary bands which occur close to the base of the series containing the same species of fossils over so large an area. This is the case from Baroda to Jubbulpoor and Nagpoor.

conclude that the period of their formation differs by a very large portion at least of the time during which the traps accumulated.

Throughout the middle and higher traps of the Deccan, even to Mahableshwar and the other higher plateaus, no trace of any sedimentary intercalated bed has been found; all appear confined to the lowest flows, cropping out round the edge of the trap area, or to the highest flows, appearing only at Bombay.

11. *Theories of formation of the intertrappean beds.*—Mr. Hislop, who has perhaps given more attention to the intertrappean rocks than any one else, and to whom we are indebted for the only complete account of the fossils, has proposed the following theory of the formation of these beds.* He considers that all Central and Western India was an immense lake communicating with the sea to the eastward near Rajamundry; that in this lake deposits containing remains of animals and plants accumulated; that these deposits were covered over by trap, and then that a second eruption of trap was injected between the fresh-water bed and the surface of the underlying rock.

Mr. J. G. Medlicott† showed that this theory was irreconcileable with facts observed by him in the Nerbudda Valley. If it were correct, the lower surface of the sedimentary bed must have been altered, whereas in every instance he had seen the upper surface alone had been changed by the trap flow above it, the under surface remaining unaltered. He says—"in every case within our experience the sedimentary beds have been deposited tranquilly on the previously indurated and moreover previously denudated surface of the trap rock." My own observations, I may say, entirely coincide with Mr. Medlicott's.

Mr. Hislop‡ in a later paper considered that both upper and lower traps might be portions of one flow, and brought forward fresh evidence in favor of his views. To enter into these in detail would

* Quar. Jour. Geol. Soc., Vol. XI, p. 368.

† Mem. Geol. Surv. Ind., Vol. II, p. 206.

‡ Quar. Jour. Geol. Soc., Vol. XVI, p. 155.

take too much time; they are by no means sufficient to prove more than local disturbance. I would suggest that the anastomozing bands to the right of the sketch, fig. 2, page 157, are the result of infiltration*, as in the similar instance figured by Newbold, (Jour. Roy. As. Soc., Vol. IX, p. 33,) to which Mr. Hislop refers in a note. This also was Newbold's view. That the sedimentary beds differ in colour from the subjacent amygdaloid† is scarcely proof that they were not deposited upon it, nor even that they were not composed in part of detritus derived from it.

Besides the objections pointed out by Mr. Medlicott, there are, I think, several others to the acceptance of Mr. Hislop's theories. In the first place, the existence of a lake several hundreds of miles in length and breadth, yet so shallow throughout the greater portion of its area that pulmoniferous mollusca *(Lymnea, Physa)*, could inhabit it, appears to me an anomaly. Secondly, Mr. Hislop's theory does not account for the cases of two or more distinct successive deposits alternating with trap.‡ If it be argued, as Mr. Hislop appears to do, that these were originally one deposit and were separated by intrusive masses of igneous rock, the reply is that their distinctness of deposition is proved by two successive deposits frequently differing entirely from each other in mineral character.§ Above all, how is it that the trap, if intrusive,

* Since the above was written, I have seen the place, and find my suggestion correct.

† l. c., p. 155.

‡ See Mem. Geol. Surv. Ind., Vol. II, p. 201.

§ Since the above was written I have received from my colleague, Mr. Fedden, the following section of the well known Mekulgundi Ghat south of the Pem Gunga River and formerly described by Malcolmson:—

1. Trap.
2. Cherty bed containing *Cypris*, *Unio*, &c.
3. Trap.
4. Limestone containing *Cypris* and fragments of small mollusca.
5. Trap.
6. Calcareous grit containing broken shells.
7. Metamorphic rocks.

Here not only do the beds successively interstratified with the trap differ in character, but also to some extent in the fossils contained, the *Unio* being confined to No. 2.

is always inserted either between the strata of the intertrappeans or between them and the underlying rock, frequently Damuda or Mahadeva sandstone and shale, and never between the beds of the latter? Lastly, the idea of a mass of fluid, such as liquid lava, being intruded throughout immense distances, in this case for hundreds of miles, between two pre-existing strata, instead of forcing its way to the surface through the first crack it meets with, is, to my mind, opposed to the first principles of physics. Any fluid forced up from below, be it liquid lava, or water, or gas, will unquestionably follow the course in which it meets with least resistance, the "line of weakness" in short. How can this be a horizontal fracture of immense extent, by intrusion into which not only enormous friction has to be overcome, but the whole superincumbent mass of rock has to be lifted bodily? Meantime the surface of the earth is only a few hundred feet above, and all that is to be overcome to reach it is the friction produced by the lateral pressure of the walls of any vertical crack, a resistance diminishing with every foot of rise. If the earth's surface be many thousands of feet above, instead of a few hundreds, the argument is so much the stronger; with the increased pressure the resistance to horizontal intrusion will augment in every instance, and the easiest road for the pent up fluid to escape must be the shortest leading to the surface. This argument is susceptible of very wide application. If all geologists would bear it in mind when studying igneous rocks, we should hear very much less of granitic and volcanic "intrusions" than is the case at present, and we should, I suspect, find that instead of being the most prevalent and effective, they are amongst the least important of the forces which operate and have in past times operated to change the surface of the globe.

I believe, then, that Mr. Hislop's, and I may add, Dr. Carter's* theory of the horizontal intrusion of beds of trap is not only opposed

* See Jour. Bombay Br. Roy. As. Soc., Vol. V, p. 257-258.

to observed phenomena, but that it involves a series of physical impossibilities.

Of course it is highly probable that local instances do occur of small intrusions of trap being inserted among and beneath the bed of the intertrappeans. I believe I have myself seen one instance. But there is a wide difference between a merely local intrusion, extending in each instance probably for but a few yards, and very possibly issuing from the overlying bed at the period of its deposition, and the injection of a mass of igneous matter throughout hundreds of square miles of country.

I am disposed to believe that the beds of the intertrappeans have each but a small lateral extension. I have certainly seen them thin out and disappear within a few miles, and have never succeeded in tracing them to any distance. Mr. Hislop considered that he had traced them continuously from Nagpoor to Ellichpoor. Mr. Wynne and I only found them in a few isolated spots in the intermediate country, and we searched in vain in many places for any indication of their existence.*

To me the occurrence of lacustrine deposits interstratified with trap flows appears so natural a phenomenon that their absence would be more remarkable than their presence. For when first lava flows are poured over the irregular surface of a country shaped by sub-aerial denudation, as the surface of India appears to have been shaped before the first volcanic outbursts, hollows must be filled up and rivers dammed, so that shallow lakes will be formed. These will not, in all probability, be of any large size. Fresh flows of lava will fill up the first lakes, but by damming up other hollows, will produce new ones, and so on, until by the constant accumulation of volcanic material the land has either been reduced to a plane, or the intervals between different lava flows are

* Quar. Jour. Geol. Soc., Vol. XI, p. 363.

too short to allow of the accumulation of sedimentary deposits. It is even possible that the region may have become barren and desolate, unfitted for organic existence, or that, from changes in the meteorological conditions caused by the volcanic phenomena and the destruction of vegetation, rain might cease to fall in the country. These last are mere conjectures, perhaps improbable, and scarcely warranted by the conditions of any known existing volcanic region, but no existing volcanic region approaches in magnitude to that of the Deccan. It is in any case easy to understand that when rest from volcanic disturbances, showers of ash, and lava flows, permitted sedimentary deposits again to accumulate in the intervals between eruptions, the old lacustrine fauna of the district had died out, and the change had taken place, which is indicated by the fossils of the Bombay intertrappeans. It is also in accordance with probability, I think, to suppose that the volcanic energy was less, the flows more partial, and the periods of intermission longer, at the commencement and towards the close of the trap epoch, than in the middle of the period.

The above theory, I think, accounts naturally and easily for all the phenomena of the Central Indian and Bombay intertrappean beds. It explains why the sedimentary beds sometimes occur at the base of all the traps; it accounts for several successive deposits, for their limited and irregular distribution, and also, though I confess less completely, for their absence in the great mass of the trap formation.

12. *Geological age of Deccan and Malwa traps.*—There is yet one more question to be treated, and that is the geological age of the traps. The latest and most important contribution to this subject is again Mr. Hislop's paper, so often quoted. He concludes that the traps are of lower eocene age. The same opinion has been held by others, and I entirely coincided in it myself until very lately. Mr. Hislop's arguments are,—the great similarity between the freshwater shells of the

intertrappeans and those of the plastic clay found at Rilly la Montagne, in Belgium, several points of similarity between the flora of the intertrappeans, and that of the London clay, and, especially, close resemblances between mollusca of the nummulitics of N. W. India and those found at the localities already mentioned near Rajamundry.

It will be seen that the evidence, although strong, is imperfect. Similarity of specific forms may imply, not identity, but merely approximation of geological age. That which I have to notice, therefore, will not in the least affect Mr. Hislop's arguments, but will tend, I think, to favor the idea that the traps may be rather older than lower eocene.

It has for some time been known that marine fossiliferous rocks of cretaceous age exist in the western part of the Nerbudda Valley. The fossils were first discovered near Bagh by Lieutenant (now Colonel) Keatinge in 1856, and briefly described by Dr. Oldham in the Journal of the Asiatic Society of Bengal for 1858, Vol. XXVII, p. 122, and by Dr. Carter in the Journal of the Bombay Branch Royal Asiatic Society, Vol. V, p. 621. Some of the same collection of fossils, amongst which Echinodermata prevailed largely, furnished the material for a recent paper by Dr. Martin Duncan,* in which the exact horizon of the Bagh beds was shown to be that of the Upper Greensand of Europe.†

In 1861 Mr. Rogers, the Collector of Surat, found nummulitic limestone in situ at Turkesur, close to Surat. The occurrence of limestone containing nummulites had previously been noted, a few miles further north, by Dr. Malcolmson and Major Fulljames, but the details

* Quar. Jour. Geol. Soc. of London, Vol. XXI, p. 349.

† There are some minor errors regarding localities in Dr. Martin Duncan's paper to which I shall refer elsewhere. I scarcely think, too, that all his geological conclusions are borne out by the evidence adduced, but there can be no question of the Bagh beds being middle cretaceous.

were not published before 1862, when Dr. Carter* made them known. He had previously mentioned the occurrence of nummulites in the Rajpipla hills in his "Summary of the Geology of India." These beds containing nummulites have been carefully examined by the survey and found to extend along the edge of the traps from near Surat to the neighbourhood of Broach. The fossils collected from the lowest beds have been partly determined by Dr. Stoliczka, and are unmistakably lower eocene (Parisien).

Thus lower eocene and middle cretaceous beds were known to exist in immediate connexion with the traps, but nothing whatever had been ascertained of their relations to the volcanic rocks. One of the most interesting geological questions in Western India was to ascertain these relations.

This has now been done with the following results. The lower eocene beds of Surat rest quite unconformably upon the traps, and there is clear evidence of an enormous amount of denudation of the latter, both before and during the deposition of the nummulitic beds. Not only do the eocene rocks rest upon the denuded edges of the traps, but materials derived from the latter enter largely into their composition, a thick conglomerate of rounded trap pebbles forming the base of the nummulitics in many places, and hundreds, perhaps thousands, of feet of gravels occurring in them, the pebbles of which are chiefly agates derived from the trappean rocks.† There can thus be no question that the lower eocene beds are much newer than the volcanic series of Malwa and the Deccan.

There is also unconformity between the traps and the middle cretaceous beds of Bagh, and this unconformity is, in places, very

* Jour. Bombay, Br. Roy. As. Soc., Vol. VI, p. 164.

† Some of these beds of pebbles west of Broach furnish the agates, carnelians, &c., which are worked by the lapidaries of Cambay.

considerable. The cretaceous beds appear in some localities to have been greatly denuded before they were covered by the trap flows. But there is never much difference in the dip of the two series; where the cretaceous beds are inclined, the traps, as a rule, are inclined also, and although the Bagh beds appear in one or two places to have been a little disturbed before the commencement of the trap epoch, such occurrences are very rare and exceptional; in very many cases the former have scarcely undergone any denuding action before they were covered by the traps. Over many hundreds of square miles, west of Bagh, a thin bed of calcareous conglomerate or limestone which represents the cretaceous rocks, and which is not more than 30 to 50 feet in thickness, is found uniformly at the base of the volcanic series. Here and there it has been cut away, as if by a stream, but it is rarely wanting for many yards. Indeed the uneven surface upon which the traps are deposited prove that the denudation undergone by the Bagh beds was purely sub-aerial, and due to rain and rivers, whereas the denudation of the traps before the deposition of the nummulitics may have been marine.

Far more numerous and better sections were met with of the base of the traps resting on the cretaceous rocks than of the bottom of the nummulitics resting on the traps, but so far as it has been possible to judge, the amount of denudation of the Bagh beds prior to the deposition of the traps was less general, and also less in amount than the denudation of the traps before the deposition of the nummulitic series; and therefore the conclusion to be drawn from the geological evidence is, *that the lowest traps appear to differ less in age from the middle cretaceous beds of Bagh than the highest traps do from the lower eocene formations of Surat.*

There is also a little palæontological evidence, but it is of small value when compared with the geological. In some beds beneath the traps

near Ellichpoor, which appear to represent the Bagh beds, Mr. Wynne found freshwater shells, one of which, a *Melania*, is closely allied to *M. quadrilineata*, Sow.

Again, there are some strong resemblances between some of the fossils of the Rajamundry intertrappeans and those of the cretaceous beds of Trichinopoly,* resemblances quite as marked as those pointed out by Mr. Hislop between the former and the nummulitic beds of Sind. Exact identity can scarcely be expected, the Rajamundry band being, I think, estuarine, while all the Trichinopoly beds are purely marine. It is by no means impossible that the Rajamundry beds may have been contemporaneous with the uppermost strata of the Arrialoor group† of Southern India.

The evidence, it will be observed, is still far from conclusive, but it appears highly probable that part, at least, of the traps are upper cretaceous in age. It is even possible that the lower traps (with the intertrappeans of Nagpoor, the Nerbudda, Berar, &c.,) might be middle cretaceous. The eruptions which produced them may have continued throughout a long period of geological time, and the uppermost flows of Bombay and Mahableshwar might even have been contemporaneous with the oldest tertiaries.

* Until the examination of these fossils by Dr. Stoliczka, now in progress, be completed, it is impossible to say if any identifications can be made.

† Mem. Geol. Surv. Ind., Vol. IV, p. 127.

POSTSCRIPT.—I have omitted in the preceding paper to notice in detail opinions upon the traps expressed by many writers, because to have examined into every question seriatim, would have taken too much space. Most Indian geologists have made observations under circumstances of considerable difficulty; many of them have never had the opportunities which European geologists possess of access to libraries and museums, or of communication with the leading scientific men of the day. That some crude ideas, distinguished more by originality than by probability, should have been put forth by men thus isolated, especially upon the subject of rocks so remarkable in many respects as are the Deccan and Malwa traps, is not to be wondered at, and it is quite unnecessary to call attention to them.

Amongst these I have, however, from inadvertence, allowed the remarks of the Brothers Schlagintweit to remain unnoticed, and as these gentlemen possessed the advantage of previous scientific training and some European experience, and had even attracted the attention of geologists in Europe before their mission to India, their opinions evidently deserve attention. I am sorry, however, that I find myself unable to agree with them. They consider (Report of the Proceedings of the Officers engaged in the Magnetic Survey of India, No. I, p. 6,) that the traps are unstratified, and also that they were poured out at the bottom of the sea. This last view was subsequently modified by Adolphe Schlagintweit (Report No. VI, p. 34,) who, after seeing more of the country, came to the conclusion that the "effusion had taken place at the bottom of extensive freshwater lakes." I have already given reasons for coming to a different conclusion, and as especial proof of the sub-aerial origin of the traps, I would point out the extreme irregularity of the surface upon which they rest. Yet, although this irregularity is so great that in places, as in the Vindhyan hills, north-west of Hoshungabad, vallies in the subjacent formations, upwards of 1,000 feet in depth, have

been filled by the traps, cases are common in which no sedimentary deposits whatever underlie the volcanic rocks at the very bottom of these valleys,—a circumstance which would be scarcely possible if the valleys were sub-aqueous at the period of effusion of the traps. Besides, the sedimentary deposits, where they do occur beneath the traps, as near Bagh, have frequently undergone denudation, and, I think, clearly, sub-aerial denudation, before the trap period. As to the absence of stratification (a view never, so far as I am aware, held by any previous Indian observer except Jacquemont), if the constant alternation of different kinds of basalt and amygdaloid, the frequent interbedding of volcanic ash, the numerous occurrences of distinctly sedimentary beds clearly interstratified for miles along the hill sides with the ashes and lava flows, are not evidence of stratification, it is difficult to conceive what evidence would suffice. Where the observations of the Messrs. Schlagintweit can have been made, which induced them to state that "the horizontal lines of separation between different layers of traps ...... are certainly no lines of demarcation between different streams of lava," that is, I presume, that the horizontal lines in question do not correspond to divisions between rocks differing in mineral character, I am at a loss to conceive.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

VOL. VI., Pt. 3.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR-GENERAL OF INDIA IN COUNCIL,

UNDER THE DIRECTION OF

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Fellow of the Royal and Geological Societies of London; Member of the Royal Irish Accademy; Hon. Mem. of the Leop.-Carol. Academy of Natural Sciences; of the Isis, Dresden; of the Roy. Geol. Soc. of Cornwall: Corr. Mem. of Zool. Soc., Lond., &c., &c.,

SUPERINTENDENT OF THE GEOLOGICAL SURVEY OF INDIA.

CALCUTTA:

PRINTED FOR THE GOVERNMENT OF INDIA.

SOLD AT THE

GEOLOGICAL SURVEY OFFICE,

OFFICE OF SUPERINTENDENT OF GOVERNMENT PRINTING,

AND BY ALL BOOKSELLERS;

LONDON: WILLIAMS AND NORGATE.

MDCCCLXIX.

CALCUTTA:
OFFICE OF SUPERINTENDENT GOVERNMENT PRINTING
1869.

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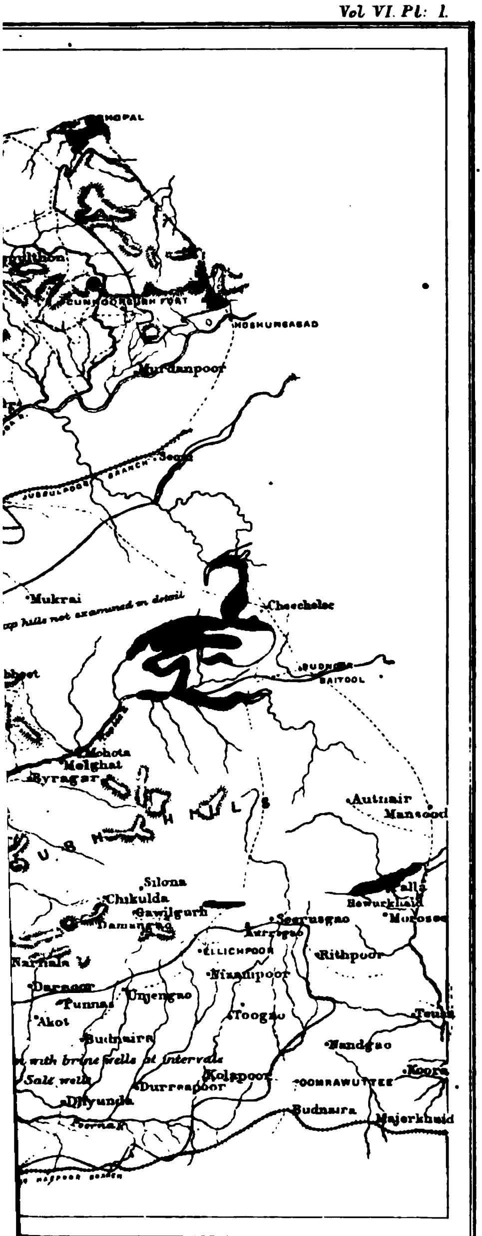
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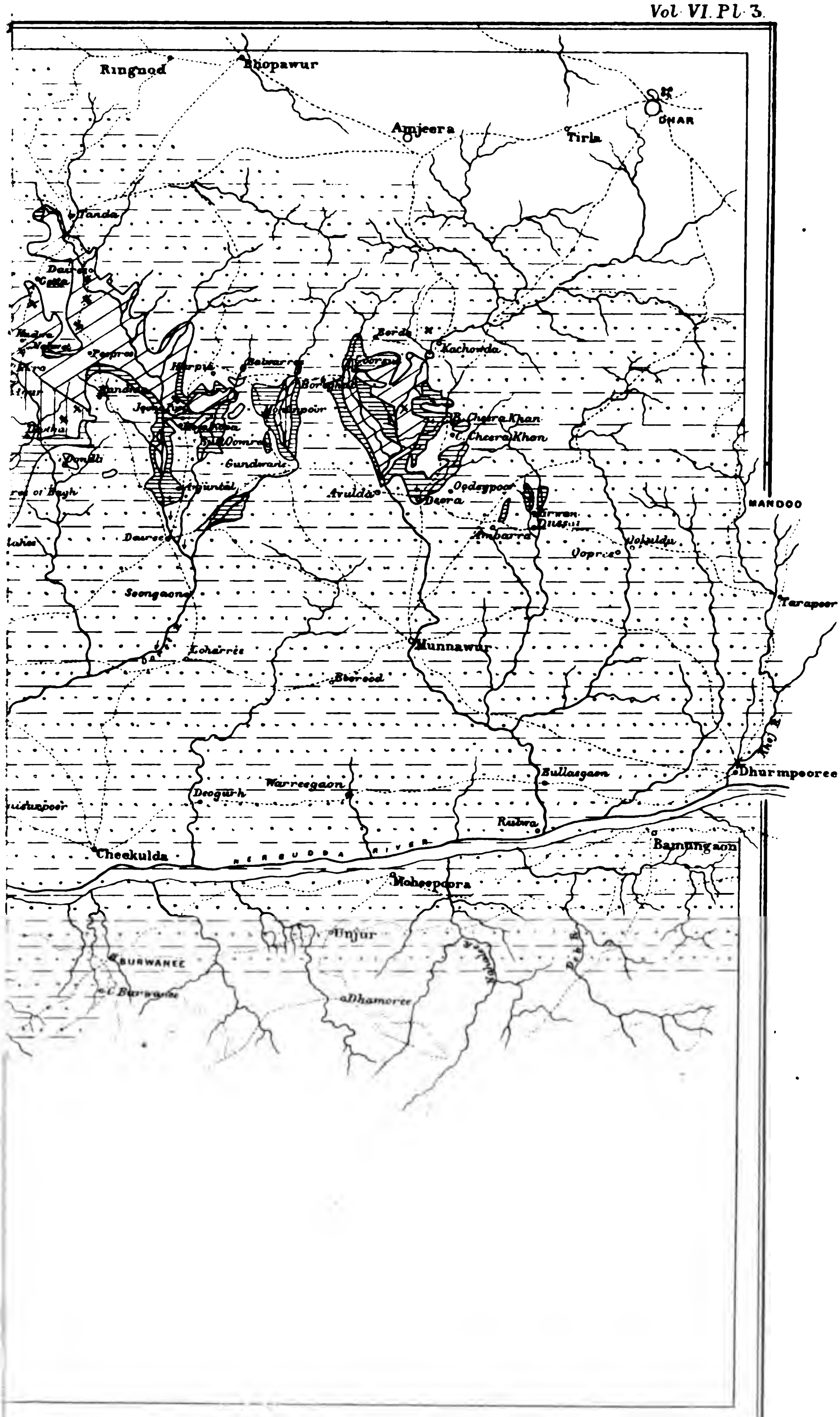
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Unjur
BURWANEE
C. Burwanee
Dhamoree

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the GEOLOGY *of the* TAPTEE AND LOWER NERBUDDA *valleys and some adjoining districts, by* WILLIAM T. BLANFORD, *Assoc. Roy. School of Mines,* F. G. S., C. M. Z. S., &c., *Deputy Superintendent of the Geological Survey of India.*

PART I.

GEOLOGY OF THE COUNTRY GENERALLY CONSIDERED.

CHAPTER 1.—INTRODUCTORY.

Area described.

The tract of country described in the present report comprises the western portion of the Nerbudda valley from Hoshungabad to the sea, and nearly the whole valley of the Taptee and its tributaries, with the exception of the southern part of Khandeish. It also includes a small portion of the Malwa and Bhopal table land, north of the Nerbudda drainage-area, and so much of the Upper Wurda valley as is comprised in Sheet 54 of the Indian Atlas. To the west it is bounded by the sea from the Mhye to the Taptee. The whole extent from east to west is about 360 miles, from north to south the breadth varies from 175 to 80 miles, the average being nearly 150.

Politically this region consists—in the east, of portions of the Bhopal, Dhar, and Indore States, to the north of the Nerbudda; of part of Hoshungabad district, nearly the whole of Baitool and a portion of

Nagpoor, in the Central Provinces, and the greater part of East and West Berar;—in the centre, Alleerajpoor and Bagh, north of the Nerbudda, the Nimar district of the Central Provinces, a large tract belonging to Indore, the States of Burwanee, Akranee, and Kantee, and the northern portion of Khandeish;—and to the west, Chota Oodipoor, the Mewassee States and Rajpeepla, all included in the Rewa Kanta, together with the Gaikwar's territories around and south of Baroda, and portions of the districts of Broach and Surat.

States and political divisions included.

The topographical maps employed during the survey, and from which the accompanying geological map is compiled, vary greatly in value, and in some portions of the country, as in the Baitool district of the Central Provinces, and the wild regions of Akranee, Kantee, &c., in the Western Satpooras, none whatever could be obtained, so that the geological lines had to be laid down on a rough sketch of the country, made by watch and compass. A very large portion of the area mapped consists of trap, and throughout this, it was only necessary to ascertain the absence of any other rock, which was frequently satisfactorily effected by an examination of the pebbles in the streams flowing from the several hill ranges, without devoting time to a close examination of their interior valleys. Except in Berar, nothing like a thorough topographical map was available in any of the more hilly tracts of the country; the greater portion of the area was only laid down with approximate accuracy on the route-survey maps of the Quarter Master General's Department, which, although admirably adapted for the objects for which they were intended, and indeed excellent maps for all ordinary purposes,* could not possibly be so accurate in their details as is necessary in order to form the basis

Topographical Maps available for.

* It is only fair to say, that such maps as Captain Pollexfen's of the Rajpeepla country, and Major Baigie's of the Nerbudda valley, are good useful maps, and far superior to much that has been printed in the Atlas Sheets as delineations of the physical geography of the country.

of a complete geological survey. The map which accompanies this report is, therefore, in many parts merely a general (though, it is believed, an approximately accurate) sketch of the geology of the country, similar to the adjoining map of the Central Nerbudda valley by the late Mr. J. G. Medlicott. The geological examination has necessarily been somewhat unequal, more time having been devoted to the portions of the country in which fair maps were obtainable, and where the geological formations were varied and important, than to those in which, owing to the imperfection of the maps, detailed geological surveying would have been simply waste of time, and in which the rocks are uniform in character.

Arrangement adopted in the present Memoir.

In consequence of this inequality and of the large tract examined, the plan adopted in describing the country in the present report differs somewhat from that generally employed in these Memoirs. Instead of relating all the observations upon each group of rocks under one head, it has appeared more advisable in the first part of the report to give a general description of each formation, of the rocks composing it, the area occupied by it, and its relations to the beds above and below, and in a subsequent part, to divide that country into the most natural and convenient sections practicable, and, under each, to give such details as have been noted on all the rocks in that division. A great advantage of this method is that any one interested in the general geological description of the country will be able to learn the views put forward without having to wade through a mass of details, while these latter, so far as they have been observed, will be found, for each neighbourhood, collected under one head instead of being dispersed under several: the latter plan, in a report relating to so large an extent of country, rendering it, as the writer has often found, a matter of difficulty and requiring some time to ascertain what has been observed in each special district. The present arrangement, it is hoped, will thus render this report more easily available both to the student of the geology of India in general and to local geologists.

Time occupied in survey:

Surveyors.

The survey of the country here described has occupied four working seasons (1862-66). In 1862-63, Messrs. Wynne and Wilkinson, who had then just reached India, were engaged with the writer in surveying the extreme western portion of the area, south of the river Nerbudda. After 1863, Mr. Wilkinson was engaged elsewhere, and he soon after was obliged by ill health to quit the survey; Mr. Wynne and the writer remaining to complete the Nerbudda and Taptee country. In 1863-64 the whole line of the Nerbudda from Hoshungabad and Bhopal to Bagh and Burwanee was examined. In the next year the north-west of the map, now published, was surveyed from Bagh to Oodipoor, and in 1865-66, besides some traverses across the trap area of the Deccan, the whole of East and West Berar, Baitool, and the greater portion of Nimar were added to the area examined. In compiling the present report use has been made of the labors of Messrs. Wynne and Wilkinson, of the former especially. To Mr. Wynne's pencil also are due the sketches made use of as illustrations, while all the western portion of the map has been compiled by the same gentleman from a number of maps of varying scales and degrees of accuracy.

CHAPTER 2.—PREVIOUS OBSERVERS.

No general account ever published before.

As is usually the case in large districts in India, different portions of the area, described in the present Memoir, have received some attention from Indian geologists, although no general account of the whole by any one observer has ever been published; and the only attempt at a general description, that given in Dr. Carter's 'Summary', is necessarily a compilation of isolated observations of varying degrees of accuracy.

Writers mentioned by Mr. Medlicott.

Very many of the writers who have described portions of the lower Nerbudda valley and the neighbouring country are mentioned in Mr. J. G. Medlicott's Memoir upon the adjoining districts to the eastward in the 2nd vol. of these Memoirs,

and in the list given by Mr. Oldham as an appendix to that Memoir at p. 337, by far the greater number of the publications are named in which the geology of the western portion of the Nerbudda country is described. A supplementary list, consisting chiefly of papers on Malwa and Eastern Guzerat, is herewith appended. The majority of the papers referred to are also contained in that most useful reprint of the 'Geological papers on Western India,' published by the Government of Bombay in 1857, under the able superintendence of Dr. Carter, a compilation which entitled Lord Elphinstone, the Governor of Bombay, and Dr. Carter to the gratitude of all interested in the progress of geology in India(a).

Different portions of area have received different amounts of notice.

As might be supposed some portions of these extensive regions have received far more notice than others. The neighbourhood of the large stations of Mhow and Indore, and of the great road leading through them from Bombay and the Deccan to Gwalior, Agra, and the other cities of the North-Western Provinces, and also the rich and populous districts of Surat and Broach, have received far more attention than the wild jungle-clad tracts which intervene. The geological formations seen on the high road from Malwa to Guzerat have more than once been described, while the roadless tracts of the Satpoora mountains and of the Dhar forest have remained unknown.

Sub-division of area.

The whole area may thus be divided into three portions, each of which has been noticed by separate observers. These are—1st, the Nerbudda valley and its neighbourhood from Hoshungabad to Baroda; 2nd, the countries lying south of the Nerbudda to the eastward, including Baitool and Berar; and 3rd, Eastern Guzerat, Broach, Surat, and their immediate neighbourhood.

(a). It is difficult to over-estimate the obligations of the officers of the Geological Survey engaged in Western India to the Government which authorized and the Editor who superintended this most useful and admirable reprint. The advantage of having all the most important publications on the geology of a large country in a portable form, so that they can be referred to in the field, is very great indeed.

The Taptee valley in Khandeish has attracted scarcely any observer, and indeed presents few features of geological interest.

1. Nerbudda valley.

The earliest observer of the western part of the Nerbudda valley, who has left any account of its geology, appears to have been Captain Dangerfield, whose appendix to Sir J. Malcolm's "Memoirs of Central India" has already been referred to by Mr. Medlicott in these Memoirs. In a paper previously published in the transactions of the Literary Society of Bombay (*a*) entitled "Some account of the caves of Bagh called the Panch Pandoos," Captain Dangerfield briefly described the rocks occurring there, and mentioned the iron manufacture then existing in the town, but which has since been given up on account of the want of fuel. In his description of the "Geology of Central India" (*b*) Captain Dangerfield treats principally of regions lying to the north and east of those now under description, and comprised in the area formerly surveyed by Messrs. J. G. and H. B. Medlicott. He, however, examined a portion of the more western country, and has made some excellent observations on its geological features. He describes somewhat minutely the characters of the southern scarps of the Malwa plateau, north of Mundlaisur, and the horizontal trap beds of which it consists; of these he counted 14. He thinks that the several beds increase in thickness below, the uppermost being 15 to 30 feet thick, the lowermost, 300. This is in the main correct, though the increased thickness of the beds below is partly apparent, and due to the sharp lines which mark the separation of the upper beds, being, towards the base of the cliffs, much concealed by talus. Nevertheless the bottommost bed is very often of great thickness, a circumstance due probably to its having filled hollows in the pre-existing surface of the country.

Dangerfield, 1818.

Dangerfield, 1823.

(*a*). Vol. II, p. 194.

(*b*). Malcolm's Central India, Vol. II, p. 318: Geol. papers on Western India, p. 231.

Captain Dangerfield also described the Nerbudda valley above and below Mundlaisur. In the upper part he mentions the iron smelting of Katkot and Chandgurh, and refers to the occurrence of *Ammonites* in the bed of the Nerbudda near Oonkar Mandatta, an island in the river a little above Burwai, on which stand some famous temples. This curious statement is probably due to some mistake (*a*); no such fossils have been found by more recent observers, nor is it probable that any really occur at the spot indicated. Dangerfield mêntions the occurrence of basaltic columns near Mundlaisur, and describes the alluvium of the Nerbudda near that city. He also gives an account of the occurrence of earthern vessels and bricks imbedded in the alluvium at Muhésur, and refers to the report that the ancient city of the same name, together with Oojein and 80 other large places in Malwa and Bagur, were, at a very remote period, overwhelmed by a shower of earth (*b*). To this story Captain Dangerfield does not appear to

(*a*). It appears almost impertinent to suggest that the *Ammonites* might have been shells of *Planorbis*, yet I see no other probable way of explaining the difficulty. They are said to have been accompanied by *Buccinum* and a species of mussel, and to have occurred in marl and earthy limestone. The fossils near Bagh occur in earthy limestone, but *Ammonites* are rare, and so are any shells resembling *Buccinum*, and the most abundant fossils are Echinoderms *(Hemiaster)* to which Dangerfield does not refer. But no Bagh beds are known to occur near Oonkar (or Oonkarjee, as it is more commonly called), and the marls and earthy limestones are probably the river deposits, which contain *Paludina* and *Melania*, either of which might have been mistaken for *Buccinum* and *Unio*. With the vague knowledge of natural history necessarily prevalent in India at the period, and the impossibility of reference to such few books as then existed, or to museums, it is not surprising that such errors should have been committed as to mistake these shells *Paludina* or *Melania* and *Planorbis* for *Buccinum* and *Ammonites*, and precisely similar errors were committed many years later by Voysey and others.

(*b*). This very curious native story, which is totally unfounded, has, unfortunately, obtained a wide circulation, like the equally absurd tale of the eruption of Denodur hill in Cutch, both being prominently mentioned by Sir C. Lyell in his Elements of Geology. The earth covering the ancient Muhésur (if, indeed, anything more than a few bricks and waterpots be imbedded) is ordinary river alluvium, and I learn from Captain Melliss, lately Executive Engineer at Mhow, and a good geologist, that the same is the case at Oojein, as was indeed long ago suggested by Colonel Sykes in his paper on the geology of a portion of the Dukkun (Geol. Trans., Ser. 2, Vol. IV). Mr. Fraser, who visited Oojein, thinks (Geol. Trans., Ser. 2, Vol. I, p 141,) that the old town probably decayed, and that the tale of its destruction is a myth. The stories of the occurrence of volcanic craters filled with water

have attached much faith, for he mentions the absence of recent volcanic action in the country around, although he refers to the stories of craters existing in the Vindhya and Rajpeepla hills. These stories the general geological investigation of the country has shown to be quite unfounded.

The concluding portion of Captain Dangerfield's paper contains a description of the country on the road from Malwa to Guzerat through Allee and Chota Oodipoor. His mineralogical observations are excellent, and have frequently been corroborated by the present survey, and his demarcation of the trap boundary on the Lower Nerbudda is a rough but good sketch. His other boundaries are less correct.

Stewart, 1821.

In another volume of the same transactions, Captain John Stewart gave some "Geological notes on the strata between Malwa and Guzerat (a)." This is another account of the rocks met with in a journey from Mhow to Baroda *viâ* Dhar, Kanas, Rajpoor, and Tejgurh.

Fraser, 1822.

A very interesting account of the geological features of the country traversed by Mr. James B. Fraser on his way from Delhi to Bombay *viâ* Neemuch, Mhow, Mandoo, Bagh, the Sindwa Ghât, Khandeish, and Nassik (b), deserves more attention, as although only entitled "Description accompanying a collection of specimens," it is not, like many papers of the period, a mere enumeration of names of rocks seen, with minute mineralogical details, which are now known to be of comparatively small importance. Mr. Fraser observed the very marked stratification of the traps forming the Malwa Ghâts, and his estimate of the number of beds is pretty nearly the same as Dangerfield's, 15 or 16. He appears to have been the first to notice the limestone, of which so many of the palaces and mosques

in the Rajpeepla hills appear to be due to the existence of a so-called lake upon the plateau at Toorun Mull, but this is palpably an artificial tank of large size, the water being dammed by a bund, as was noticed by Lieutenant C. P. Rigby. Trans. Bombay Geog. Soc., Vol. IX, p. 1.

(a). Trans. Bomb. Lit. Soc., Vol. III, p. 538.

(b). Geological Trans., Ser. 2, Vol. I, p. 141.

of the old Mahomedan city of Mandoo are built, and the source of which was unknown until a few years since (1856). He also describes the metamorphic rocks and sandstones of the neighbourhood of Bagh. As an example of the excellent observations recorded in this interesting paper, which has been unfortunately omitted (*a*) from the 'Geological papers on Western India,' the remarks on the difference in appearance between the Vindhya and Satpoora hills may be mentioned, the former being flat on the top, while the latter are "bold and romantic in their outlines, rising into lofty peaks, and swelling into shapes which would induce the beholder from a distance to consider them as primitive," which is literally the fact (*b*).

Jacquemont, 1832.

Jacquemont (*c*) in 1832 (published 1841) marched through Mhow, Mandoo, Mundlaisur, Asseergurh, and Boorhanpoor, on his road from the Upper Provinces to Bombay. He observed the terraces on the hills near Mandoo, and also on the rises which are found upon the table land about Indore and Mhow, but insists that these are not the result of stratification (*d*), of which he declares that no trace can be found in the beds. So far as small specimens are concerned (and it is of these he is treating in one instance, at p. 593), this is true, but nothing can be clearer than the superposition of distinct beds, differing frequently in mineral composition. Jacquemont noticed the limestone at Mandoo, but appears to have doubted if the grains it contains are organic. He makes a few remarks on the alluvial deposits of the Nerbudda valley, and treats at greater length the subject of the traps (*e*) of Malwa and Nimar in general, and their distinctions from the volcanic rocks of Europe. His observations

(*a*). Dr. Carter in his 'Summary' mentions his inability to obtain access to a copy.

(*b*). See postea. On my first seeing the range north of Khandeish from the Rajpeepla hills I noted them as apparently metamorphic.

(*c*). Voyage dans l'Inde, Vol. III, pp. 449, 593, &c.

(*d*). The same remark has been made by Messrs. Schlagintweit; see these Memoirs, Vol. VI, p. 161.

(*e*). pp. 598, 599.

are interesting, but he appears to have been inclined to assign high geological antiquity to the traps of India, and he comments upon the resemblances they present to metamorphic rocks in their mode of decomposition (?), and the representation of the veins and strings (*filons*) of quartz and amphibol in the latter by the veins of calcspar and quartz in the trap (*a*).

Stirling, 1841-42.

In two papers published in the transactions of the Bombay Geographical Society (*b*), Major Stirling describes some of the geological features of the neighbourhood of Mundlaisur. The first paper contains observations on the alluvial deposits of the Nerbudda valley and on the rocky barrier below Muhésur (or Mheysur) at Sansadurra, which barrier, he considers, was formerly complete, and formed the dam to a lake which covered the present site of Muhésur. In the second note he describes the granite occurring in the bed of the Nerbudda river at Mundlaisur, which he considers to have been not transported boulders, but an actual protrusion of the granite through the trap. His description of the mode in which the granite and trap are intermixed is very careful and accurate, as is also the account of the same given a few years later by Captain Abbott, in the Journal of the Asiatic Society of Bengal (*c*). He arrived independently at the same conclusion as Major Stirling. Both notice the manner in which the granite and trap at the junction appear to blend into each other, and Captain Abbott suggests that this may be due to both granite and trap having been in a state of fusion at the same time. The examination of the ground by the present survey has led to somewhat different conclusions, which

Abbott, 1845.

(*a*). It is scarcely fair to criticise Jacquemont's remarks. He did not live to revise them, and his diary was printed as it stood. Many errors would doubtless have been expunged had he been able to prepare his papers for publication.

(*b*). A visit to the falls of Sansadurra, Vol. VI, p. 5, 1841, and, Notice of granite protruding through the trap rock in the bed of the river Nerbudda at Mundleysir, ibid., p. 7.

(*c*). Vol. XIV, p. 821.

will be found in the sequel. Another paper of Captain Abbott's in the same volume of the Asiatic Society's Journal describes the clay of the Nerbudda valley and some agate splinters contained in it, which he shows must have undergone fracture previously to being imbedded (*a*).

Neither Stirling nor Abbott appears to have been aware that metamorphic and other rocks, lower than the traps, existed in the Nerbudda valley at no great distance, both east and west of Mundlaisur, and they were evidently unacquainted with Dangerfield's researches.

Malcolmson, 1844.

Dr. Malcolmson, about the same time, in the transactions of the Bombay Geographical Society (*b*) identified some specimens of *Physa*, *Lymnea*, &c., collected by Lieutenant Blake near Ghara at the foot of the Nalcha Ghât (N. W. of Mundlaisur) with shells found by himself in the intertrappean beds of Berar and Nagpoor, and he concludes that the Vindhyan mountains were elevated during the same comparatively recent epoch as the Sichel, Gawilgurh and Satpoora ranges. He then proceeds to point out the importance of this determination with reference to Elie de Beaumont's theories concerning the synchronism of parallel mountain chains (*c*). A large portion of the paper is occupied by this discussion, and by remarks upon the differences presented by the climate and fauna of the Indian plains previously to the eruption of the traps and elevation of the mountain chains. The remarks are most interesting, as are all the few pages which their author has contributed to the elucidation of the geology of India, but the data upon which they are mainly founded have since been shown to be incorrect, and it is therefore unnecessary to do more than refer to them. In a foot note (p. 372), Malcolmson very briefly refers to the

(*a*). These may have been the remarkable flakes, almost certainly broken by human agency, which abound in parts of the Nerbudda valley.

(*b*). Vol. VI, p. 368.

(*c*). For some important remarks by Mr. J. G. Medlicott on this theory, see these Memoirs, Vol. II, pp. 254-263.

existence of traps of different ages, and to the alteration of the cornelian conglomerates of Broach by more recent igneous rocks. The details of his observations in Guzerat were never published, and it is now impossible to tell what were his reasons for believing in volcanic action of later date. No trace of such action has been found by the present survey in the locality mentioned.

Carter, 1854.

Dr. Carter, in his "Summary of the Geology of India, between the Ganges, the Indus, and Cape Comorin (a)" collates most of the writers already mentioned. The only additional remark of any importance was a very ingenious and happy suggestion that the 'coralline limestone,' mentioned by so many writers as having been employed in the ruined buildings of Mandoo, might be the limestone mentioned by Captain Dangerfield as met with near Bagh on his journey towards Guzerat. Dr. Oldham pointed out the great interest attaching to this question to Captain (now Colonel) Keatinge, then Political Agent for Nimar, at Mundlaisur, and this officer, in November 1856, discovered fossils at Cherakhan about twenty-two miles east of Bagh, and recognised them as being of cretaceous age. A few months later, in January 1857, he revisited the locality in company with Mr. Blackwell, and added largely to the fossils collected.

Keatinge, 1856.

Carter, 1857.

Dr. Carter, from the examination of a set of these fossils presented to the Bombay Branch of the Royal Asiatic Society by Captain Keatinge, came to the conclusion that they were of Neocomian age. Unfortunately, either from Dr. Carter's having misunderstood the details of the discovery, or from some mistakes made by Mr. Blackwell, from whom the former appears to have derived much of his information, the account given is full of errors. The merit of the discovery, which was in reality solely due to Captain Keatinge as above shown, was ascribed partly to Mr. Blackwell, and the

(a). Journal of the Bombay Branch Royal Asiatic Society, Vol. V, p. 179, and Geological Papers on Western India, p. 628.

fossils were said to have been found at the caves of Bagh, where the rocks are unfossiliferous, instead of at Doora and Cherakhan more than twenty miles further east. Even about the section at Bagh there is some mistake. It is stated to consist of

Red argillaceous limestones and clay strata	...	15—20 feet.
Sandstone	...	100 „

whereas no red argillaceous limestone is found about Bagh: the limestone which occurs there being a whitish nodular stone.

Oldham, 1858.

Dr. Oldham, who had also received some fossils with the details of their discovery from Captain Keatinge, gave brief notices of their occurrence in two publications (*a*) at least and published a full account in the Journal of the Asiatic Society of Bengal (*b*) shortly after. In this he pointed out some of the mistakes into which Dr. Carter had been led, and questioned if sufficient data had yet been obtained for assigning the beds definitely to the Neocomian or any other sub-division of the cretaceous series, while he confirmed Captain Keatinge's assignment of the rocks to a portion of that series.

Impey, 1856.

Mr. Impey, in the Journal of the Bombay Branch of the Royal Asiatic Society (*c*) gave a description of the caves of Bagh, which contains some notices of the rocks occurring in the neighbourhood.

Medlicott: Theobald, 1860.

It is unnecessary to do more than mention the descriptions by the late Mr. J. G. Medlicott and Mr. Theobald of the country to the eastward of that now surveyed in the 2nd Volume of these Memoirs.

Duncan, 1865.

The last paper on this tract which requires notice is a very valuable contribution to Asiatic palæontology by Dr. Martin Duncan, who published a list of the Echinodermata from Bagh, together with some from the south-east coast

(*a*). Jour., Mad. Lit. & Sci. Soc., February 1857: Rep. Brit. Assoc., 1857: Ed. New Phil. Jour., No. 12, p. 320.

(*b*). Vol. XXVII, p. 116. (*c*). Vol. V, p. 543.

of Arabia, in the Quarterly Journal of the Geological Society of London (*a*). In this the exact position of the Bagh beds in the cretaceous series is shown to be nearly that of the upper greensand of Europe, the fossils being, in nearly every case, identical. Unfortunately Dr. Martin Duncan has repeated nearly every mistake made by Dr. Carter in the paper already alluded to, although Dr. Duncan was acquainted with Dr. Oldham's account, and refers to it. Had he read carefully Captain Keatinge's diary quoted therein, he must have seen that the fossil locality was 2 to 3 marches east of Bagh. The geological arguments used to prove the identity of the Bagh beds with those of Ras Sharwen in Arabia appear by no means sufficient; the palæontological are of course unquestionable, but the existence in both cases of an unfossiliferous sandstone below the limestone, and the asserted neighbourhood in both cases of a great south-west fault, will not appear of much value to a geologist when he learns that the two localities are 1,500 miles from each other. It is a pity that Dr. Martin Duncan does not explain more clearly what he meant by the great south-west fault. It is probable that he refers to a remark of M. Elie de Beaumont's, in the 'Systemes des montagnes,' (*b*) that the direction of the south-east coast of Arabia is parallel to a prolongation on a great circle of the Vindhyan range on the Nerbudda. These defects in the geological portion of the paper in no way detract from its palæontological importance.

2. Countries south of the Nerbudda valley, Baitool, Berar, &c.

Dr. Voysey is the earliest writer who described any portion of Berar.

Voysey, 1833.

His paper "On some petrified shells found in the Gawilgurh range of hills in April 1823" is published in the XVIIIth Volume of the Asiatic Researches, p. 187. In this paper he gives a general account of the characters presented by the Gawilgurh range, and describes the trap rocks of which it is composed. As usual in papers of the period when Voysey wrote, much of the space

(*a*). Vol. XXX, p. 349. (*b*). Page 655.

is occupied by mineralogical details, while the really important discovery of the 'petrified shells' receives less notice. They were found on the south side of the Taptee in the ascent to the table land near Jillan. The rock in which they occurred is far more carefully described than the shells themselves, which are referred to the genera *Conus* and *Voluta*, incorrectly however, the species being *Physa Prinsepii* and other freshwater forms.

It is curious that if Voysey crossed the Taptee on the road from Baitool and Ellichpoor, as appears probable, he omitted to note the occurrence of metamorphic rocks and sandstone in the bed of the river.

Jenkins, 1834.

In the same volume of the Asiatic Researches (*a*) is a paper by Captain F. Jenkins, entitled "An account of some minerals collected at Nagpoor and its vicinity with remarks on the Geology, &c., of that part of the country." He refers chiefly to the rocks occurring in the immediate neighbourhood of Nagpoor, but some of the specimens described came from Chindwara, and, in connection with them, reference is made to the extension of granitic rocks to Baitool, and of the trap beyond Baitool in the Asseergurh and Gawilgurh hills.

Finnis, 1834.

The next paper on this region is "A summary description of the country between Hoshungabad on the Nerbudda and Nagpoor" by Lieutenant John Finnis, published in the Journal of the Asiatic Society of Bengal (*b*). This paper has already been referred to by Mr. J. G. Medlicott. It is little more than a list of specimens of rocks collected on the road, with the details of the localities whence they were derived, but so far as its scope admits, it gives a good account of the section of country traversed.

Bradley, 1845.

Dr. W. H. Bradley published in the Transactions of the Bombay Geographical Society (*c*) "Some account of the topography and climate of Chiculdah situated on the table land of the Gawil range." In this a very good description of

(*a*). Vol. XVIII, p. 1, p. 195. (*b*). Vol. III, p. 71. (*c*). Vol. VII, p. 167.

the hills around Chiculdah is given: the trap of which they are chiefly formed is described, and the occurrence of sandstone and limestone underlying the trap is noticed and commented upon. Dr. Bradley also describes the occurrence of fossils in the trap of Shepe Ghât near Ellichpoor, the name of which pass, he suggests, may be derived from the native word sepe (or rather sipi), a shell. He enters at some length into the question of the origin of the traps which he considers probably submarine. The greater portion of the paper is not geological.

Hislop, 1855.

The Reverend S. Hislop, in his various papers on the geology of the Nagpoor country, has occasionally referred to the neighbourhood of Ellichpoor and Baitool. The former station he visited on a mission tour in company with Mr. Hunter. But no detailed description is given by him of any portion of the present area.

Other papers, besides Mr. Hislop's, referring to neighbouring tracts of country, such as the Deccan and Southern Berar, serve to illustrate the geology of this area. Such are the well known papers of Dr. Malcolmson and Colonel Sykes in the Transactions of the Geological Society. But these do not refer to any portion of the country included in the present map.

3. Eastern Guzerat, including Rajpeepla.

Copeland, 1815.

One of the earliest geological notices on any part of India is an account by Mr. J. Copeland of the Cornelian mines in the neighbourhood of Broach. This paper, which was published as long ago as 1815 in the transactions of the Literary Society of Bombay (*a*) the predecessor of the present Bombay Branch of the Royal Asiatic Society gave an account of a visit from Broach to the agate mines near Ruttunpoor. The description of the mines and of the method of preparing the pebbles is excellent and

(*a*). Vol. I, p. 289. The paper appears also to have been sent to the Geological Society of London; a notice of it appears in Geol. Trans., Vol. IV, p. 447.

precisely applicable to both at the present time, probably the same may have been the case for the last two thousand years or more. The geological portion of the paper, however, is not of much value. Mr. Copeland thought that the sandstone hill near Ruttunpoor was of volcanic origin, and the following sentence is rather amusing: "We were informed that the fire damp (hydrogen gas) (*a*) was not uncommon in the mines, and that the miners did not descend till the sun had risen sufficiently to dispel the vapours."

Lush, 1836.

The next observer in this country appears to have been Dr. Lush, who published "Geological Notes on the Northern Concan and a small portion of Guzerat and Kattywar" in the Journal of the Asiatic Society of Bengal (*b*). He started from Bombay and appears to have travelled by Damaun and Bulsar to Surat and Broach; he visited the agate mines, and thence went to Kathiawar. In the southern part of the country traversed he noticed strata of sandstone containing shells and resting upon the trap (these beds are identified by Carter with the sub-recent shell-concrete of Bombay). Dr. Lush states that the trap of the coast only extends to Bulsar and Gundavee, and he evidently believed that the Rajpeepla hills were entirely formed of the same sandstone as is seen on the Kiem and at the Cornelian mines near Broach. (This sandstone in reality only skirts the hills). In describing the sandstone and conglomerate of Ruttunpoor he is quite right in correcting Mr. Copeland's statement of the volcanic nature of Bawa Gorea hill, which, as he rightly says, does not contain a trace of trap, but he is in error in supposing the gravels from which the agates (or cornelians) are procured to belong to higher beds than these conglomerates and sandstones. He remarks the absence of trap pebbles in the conglomerates of Guzerat and Kathiawar. Malcolmson subsequently, in the paper already referred to, especially speaks of their occurrence. The fact is that they are undoubtedly extremely rare, but they do

(*a*). Sic in orig. (*b*). Vol. V, p. 761.

occasionally occur and in very large numbers in particular beds near the base of the series. Malcolmson's notice of their occurrence at Perim has not been confirmed, but it is not likely that so good an observer was mistaken, and it is not at all improbable that they exist. Dr. Lush's conclusion that the trap is of later date than the conglomerates is quite untenable. On the contrary, the constituent materials of the latter appear to have been mainly derived from the waste of the former.

Dr. Lush appears, by Lieutenant Fulljames's account, to have been the first discoverer of the ossiferous beds of Perim Island (*a*) in the Gulf of Cambay. He gives a very brief but accurate description of the rocks of the island, especially mentioning their horizontality, in which he is correct, while later observers, who have supposed the beds to be disturbed, are mistaken, having been misled by their irregular bedding.

Fulljames, 1836.

Hugel, 1836.

Ethersey, 1838.

Nicholson, 1844.

Falconer, 1844.

About this time the rocks of Perim appear to have attracted considerable attention. They were described by Lieutenant Fulljames in the Journal of the Asiatic Society of Bengal, (*b*) his description being accompanied by a note from Baron Hugel on some of the fossil bones, a number of which were presented by Lieutenant Fulljames to the Society. A fuller account of the geological formations of the island was given by Lieutenant Ethersey in the transactions of the Bombay Geographical Society (*c*). His description is good. Again, Dr. Nicholson, (*d*) six years later, described the topography of the island, its rocks, the mode of occurrence of the fossils, &c., in a paper accompanied by maps and a section. Some remarks by Mr. J. Grant Lumsden were included in Dr. Nicholson's paper. Lastly, Dr. Falconer, in the Quarterly Journal of the Geological Society of London, (*e*) described the more remarkable fossils found, *viz.*,

(*a*). Not to be confounded with the still better known island of the same name in the Red Sea. (*b*). Vol. V, p. 289. (*c*). Vol. II, p. 55.
(*d*). Journal, Bombay Branch Roy. As. Soc., Vol. I, p. 10. (*e*). Vol. I, p. 356.

portions of jaws and vertebræ of *Giraffe, Dinotherium* and of a new mammalian genus allied to the *Sivatherium,* which he called *Bramatherium.*

Meantime but little had been added to the knowledge of the geology of Eastern Guzerat. Fulljames, in 1838, (*a*) described a visit, made in 1832, to the Cornelian mines so often mentioned, but his observations add nothing to those of Copeland and Lush. There is a notice in the Journal of the Bombay Branch Royal Asiatic Society (*b*) of the presentation to the Society by Dr. Malcolmson of a silicified palm tree, and of the lower jaw of a *Mastodon* discovered at Peermocha near Broach. They were found, it is said, in a marine tertiary conglomerate. If this be correct, the discovery is very interesting, as proving the existence near Broach of a series of rocks higher than the nummulitics.

Malcolmson, 1844.

Dr. Malcolmson's untimely death in 1844 prevented his observations on the Geology of Guzerat from becoming known, and his notes and paper appear to have been lost. Dr. Carter, in his 'Summary of the Geology of India,' (*c*) first called attention to the existence of nummulitic limestone in the western portion of the Rajpeepla hills. The localities are in fact west of the hills, though within the territory of Rajpeepla. In the notes to the 2nd edition of this 'Summary' published in the 'Geological Papers on Western India' (*d*) some additional details are given. Dr. Carter looked upon the conglomerate of Ruttunpoor as a probable representative of the Perim beds and as being an old beach, chiefly formed of rounded flints from the amygdaloidal rocks. With regard to the origin of the agates he is unquestionably correct: the relation of the conglomerates of Ruttunpoor to those of Perim, however, is still undetermined.

Carter, 1854.

(*a*). Fulljames, 1838, Trans. Bomb. Geog. Soc., II, 74. (*b*). Vol. I, p. 366.
(*c*). Jour. Bom. Br. R. A. S., Vol. V, p. 248. (*d*). P. 696.

Buist, 1855.

Dr. Buist published in the transactions of the Geographical Society of Bombay (*a*) "Notes on a journey through parts of Kathiawar and Guzerat." These treat of various matters of interest, some of them being geological, and including some remarks on Perim Island, and on the alluvial deposits of the plains of Surat and Broach, which Dr. Buist looks upon as of marine origin. He is inclined to dispute the assertion that the Gulf of Cambay is silting up, and considers that the land has risen, and that there is evidence of two distinct rises near Surat.

Carter, 1857.
Do. 1861.
Rogers, 1861.

Dr. Carter, in 1857, published in the Journal of the Asiatic Society of Bombay (*b*) some additional details as to the locality and species of the nummulites obtained by Major Fulljames at Wasna, not far from Broach. In 1861 he gave further particulars (*c*) showing that a similar discovery had been made by Dr. Malcolmson, and announcing other fossil localities of which an account was given by Mr. Rogers. (*d*) This gentleman met with nummulitic limestone *in situ* at Turkesur about 20 miles north-east of Surat, and at Bhadee, 12 miles further north, and thus showed that the rocks of the eocene period must be considerably developed in Eastern Guzerat.

Geological questions remaining for solution at commencement of present survey.

Before closing this portion of the subject it may be useful to call attention to a few geological questions which remained for determination at the commencement of the present survey and the importance of which had been recognized.

I.—Although the existence of nummulitic beds had been demonstrated near Surat and Broach, no attempt had been made, so far as appears from the published data, to ascertain their relations to the traps. To this question Dr. Carter especially directed attention, (*e*) as also to the connection between them and the agate-conglomerates of Ruttunpoor.

(*a*). Vol. XIII, p. 11. (*b*). Vol. V, p. 624. (*c*). l. c. Vol. VI, p. 163.
(*d*). Ibid. Vol. VI, p. 164. (*e*). Jour. Bom. Br. R. A. S., Vol. VI, p. 166.

II.—The same want of information existed as to the relations of the cretaceous rocks of Bagh to the traps. As the traps had already, by several writers, been classed with the older tertiaries, chiefly upon palæontological evidence, there was here, in the known co-existence of rocks both of older tertiary and of cretaceous age, with the traps, within a comparatively limited area, a probable test of the accuracy of that opinion.

III.—Another important matter was to endeavour, if possible, to ascertain some connexion between the Bagh cretaceous rocks and the several great sandstone groups of the Nerbudda valley, described in Mr. Medlicott's report as Mahadeva, Lameta, Damuda, &c., but which, from the rarity of fossils, and the almost complete absence of remains of animals, it had been impossible to assign with certainty to their true geological horizons.

These were the most pressing questions, but a host of less prominent, though scarcely less important, matters also called for enquiry. Amongst these were the mode of eruption, source and nature of the traps, the position of the intertrappeans, the nature and origin of the alluvium of the river valleys, and of the low ground at Guzerat, the western extension of the Vindhyan system, the relations of the peculiar rocks found in the Nerbudda, west of Hurda, to the Vindhyans, &c.

In a previous paper in these Memoirs (*a*) the principal questions relating to the traps themselves have been treated; the solution of the remaining difficulties, so far as they have hitherto been elucidated, will be found below.

CHAPTER 3.—PHYSICAL GEOGRAPHY AND ITS RELATION TO THE GEOLOGY.

Characters of Central and Western India generally.

The whole of Western and Central India from Malwa to Belgaum may be looked upon as a great table land of horizontal, or nearly horizontal, beds of trap, into which a few deep valleys have been cut. In the latter, in places, intertrappean beds are exposed, while to the west, the

(*a*). Vol. VI, p. 137.

beds of the table land have, in former times, been cut away by the sea,* as is attested by the old range of cliffs now known as the Western Ghâts. Further to the westward, along the present coast, the traps dip towards the sea, and higher rocks of tertiary age commence to appear near Surat at a low level. To the north-west of Chota Oodipoor and Baroda, the volcanic rocks have been entirely removed by denudation, and the country is hilly and irregular, but being of a lower general elevation, the valleys are less deep than in the trap area.

Direction of watersheds.

The slope of the table land is to the eastward; the whole drainage of the Malwa and Deccan plateaus without exception running to the Bay of Bengal. But, from out of the heart of the plateau, valleys are cut by the Taptee and Nerbudda, two rivers which rank amongst the great streams of the Peninsula, and which flow in the opposite direction, *viz.*, to the west. From the very verge of the cliffs which overhang the valleys of these rivers, both to the north in Malwa, and to the south in the Deccan, streams run to the Ganges or to the Godavery.

Alluvial plains in Nerbudda and Taptee valleys.

This is not the only peculiarity of the Taptee and Nerbudda valleys. Their most remarkable feature, perhaps, is the existence of the great alluvial plains which they traverse, and from which they emerge by rocky gorges. The great and fertile plain of the Nerbudda, one of the richest agricultural tracts in India, extends from Jubbulpoor to beyond Hoshungabad, and has already been described by Mr. J. G. Medlicott and Mr. Theobald in the 2nd Volume of these Memoirs. A smaller and less well marked plain, on which the alluvial deposit is thinner and less uniformly spread, extends from Burwai to the neighbourhood of Burwanee. In the Taptee valley there are two great alluvial plains, that of Berar upon the Poorna, the principal tributary of the Taptee, and that of

* This subject will be more fully discussed further on under the head of denudation.

Khandeish on the Taptee itself, below the junction of the Poorna. Both of these, though the first is far broader in proportion to its length than the Nerbudda plains, are remarkably similar in their general features.

Height of plains above the sea.

All these plains approximate to the same general height above the sea, *viz.*, about 1,000 feet; those further up the rivers being, of course, higher than those lower down, but still the difference is small compared with what takes place below them. Thus the height of the great Nerbudda plain is about 1,200 feet above Nursingpoor, and thence falls to 950 feet near Hurda; the lower plain near Mundlaisur is about 700 feet above the sea. The Berar plain is from 800 to 900 feet, the Khandeish plain, at its upper portion, about 700 to 750. The alluvial flats on the Wurda river, above Kowta, are similarly very nearly 900 feet above the sea, and the plain in the valleys of the Wein Gunga and its tributaries near Nagpoor are of the same height.*

River gorges.

The Berar and Khandeish plains join by a narrow neck, and there is but a slight fall in the river between them, but from all other plains the rivers emerge through rocky gorges in which the fall is great. This is the case with the Taptee, through the trap hills of Rajpeepla, below Kookurmoonda, and with the Nerbudda below Hoshungabad, through the metamorphic and Vindhyan rocks of the Dhar forest, and again below Burwanee at the Hurin Pal, through the traps of the Burwanee and Mutwar hills.

Hurin Pal.

Mural scarps.

All of these great plains, also, are surrounded, more or less completely, by mural escarpments, the most northern and southern of which are the edges of the table lands already mentioned. There are some very peculiar features connected with these escarpments. Before quitting the subject of the physical geography of the Nerbudda and Taptee valleys, it will be well

* My data are chiefly the Railway Sections.

briefly to describe the features of the dividing range of hills which intervenes between them.

Features of Satpoora hills.

This range, known under various names, the most widely applied of which appears to be the Satpoora,* is well defined to the westward, and from Rajpeepla to Asseergurh consists of a belt of mountainous country 40 or 50 miles in breadth, and of an average height, at the crest of the chain, but little under 2,000 feet above the sea, while many peaks rise above 3,000, and some, and even some small table lands as Toorun Mull, are as high as 4,000 feet. Nearly the whole of this range, both hills and valleys, consists of trap, but towards the west, along the northern boundary of Khandeish, a series of craggy peaks are met with such as are but rarely seen in the trap region. Elsewhere, the summit of the range is more or less a table land. Just east of Asseergurh there is a break in the range, through which the railway from Bombay and Khandeish to Jubbulpoor passes, the highest part of which is only 1,240 feet. It is worthy of notice that this break leads from close to the junction of the two alluvial plains on the Taptee and Poorna to a flat tract lying between the two Nerbudda plains. East of this break the trap hills continue till south of Hoshungabad, where sandstone and metamorphic rocks emerge, and form a great portion of the hills of the Puchmurry and Baitool country. There is a table land of considerable extent around Baitool, which extends far to the eastward beyond Chindwara and Seonee, and joins the high plateau of Umurkuntuk. Upon this plateau trap still predominates, and a great spur from it extends between the Taptee and Poorna, forming the northern boundary of Berar, as far as the confluence of those rivers. This range is also of considerable height, in places nearly 4,000 feet; like most other ranges it has no definite name and is generally looked upon as a portion of the Satpoora. The only distinctive term ever applied to it appears to be that used by Voysey, *viz.*,

* Properly the Satpoora or seven ranges comprises several other hill-chains—the Syhadree, Vindhya, &c.

the Gawil or Gawilgurh hills, which name will be employed to denote the range whenever it is necessary to refer to it in the present Memoir.

Along the extreme western portion of the map, and bordering the sea in Guzerat, there is also a rather broad tract of alluvium due probably to deposits from the waters of the great rivers Taptee, Nerbudda, and Mhye, and closely resembling the inland plains in character. It diminishes rapidly in breadth south of the Taptee, and, near Bulsar, the Western Ghâts, or more properly, the Syhadree range, may be said to commence at the north-west corner of the Deccan plateau. High ranges, however, stretch thence to the northward, and intervene between the flat ground of Khandeish and that of Surat. Between the Taptee and Nerbudda the western-most spurs of the Satpoora range, there known as the Rajpeepla hills, sink gradually towards the plain to the westward. North of the Nerbudda, as already mentioned, the hills are in general of no great height to the west; the only exceptions being the isolated trap mass of Powagurh, which rising to upwards of 2,000 feet from the plains forms a most striking feature in the landscape near Baroda.

Alluvial plain of Guzerat coast near Surat and Broach.

Hill ranges north-east of Bulsar.

Hills north of the Nerbudda.

It will also tend to facilitate the understanding of the following pages if, before proceeding to other subjects, a very brief description of the leading physical features of the Nerbudda and Taptee valleys within the limits of the accompanying maps be given.

Characters of Nerbudda and Taptee valleys.

The great alluvial Nerbudda plain extends along the river for about 50 miles* west of Hoshungabad, being much broader to the south than to the north of the river. Near Hindia the Nerbudda enters a more rocky country, covered with jungle, but in which the few hills which occur are still low, while

Alluvial plain of Hoshungabad.

* All these distances are measured in a straight line and not along the windings of the river, which would frequently double them.

to the south, away from the river, the alluvial plain extends for a considerable distance to the westward in the direction of Charwa. From Hindia to the mouth of the Chota Tawa river close to Chandgurh the rocks in the river bed are principally metamorphics; then the Nerbudda enters a tract of Vindhyan* sandstones, and runs between hills of considerable height for about 30 miles. The valley here, north of Poonassa, is chiefly occupied by Vindhyan and Bijawur rocks; it is a wild hilly tract, completely covered with jungle, and almost uninhabited, belonging to the principality of Dhar, and sometimes known as the Dhar forest, a convenient term, which it will be well to use in speaking of it. The river emerges from this rocky and jungly wilderness at Burwai, and thence flows past Mundlaisur and Burwanee for about 90 miles through an open plain, alluvial in parts and cultivated. In the western part of this open tract is the town of Bagh, and from that town to the westward about Rajpoor and Oodipoor, the country for the most part is gently undulating with scattered rises of no great size, while the river enters, at the Hurin Pal, a narrow gorge between high trap hills, which it traverses for between 70 and 80 miles, until it again emerges a little east of Nandode in an open alluvial plain, through which it runs past Broach to the sea.

Dhar forest.

Mundlaisur plain.

Rath country.

The Taptee rises near Mooltye in the trap plateau, south-east of Baitool, and traverses the table land for a few miles, when it falls suddenly into a deep gorge, in which, south-west of Baitool, rocks underlying the traps are exposed. This gorge gradually opens, but the river flows between hills of considerable height as far as Mel ghât, and between lower hills, but still in a narrow valley, to Boorhanpoor. Here the valley widens into an alluvial flat, which soon extends into the great plain of Khandeish. About 20 miles below Boorhanpoor the Taptee receives from the south the

Taptee valley.

* These formations will be described below.

Poorna, the whole course of which has been through the great Berar plain. The Taptee leaves the Khandeish plain a few miles below Kookurmoonda, and for 60 miles passes through the hilly country of Wajpoor and Mandvee; below the town of Mandvee it leaves the hills, and runs thence through the alluvial plain of Surat to the sea.

CHAPTER 4.—LIST OF FORMATIONS.

The formations which will be described in the following pages may be classed under the following heads; the groups being enumerated in descending order in this case, although in the description of each group the reverse plan will be adopted:—

Post Tertiary.	9.	Newer forms of alluvium and surface soil.
Tertiary	8.	Alluvial deposits of rivers and of the sea coast in Guzerat.
	7.	Older tertiary beds, including the Nummulitics.
Cretaceous.	6.	Deccan and Malwa traps.
		(a) Intertrappeans.
	5.	Bagh beds and Mahadeva group.
Azoic.	4.	Vindhyan series.
	3.	Bijawur series.
	2.	Champaneer beds.
	1.	Metamorphic series.

None of these names, except that of the Champaneer group, are new. All the others have been employed before in these Memoirs, and whenever it appears necessary, the reasons for adopting them in the present instance will be specified in each case, and the nameC hampaneer group will be explained in the section relating to those beds. In classing together the four lowest series as Azoic, it is intended solely to employ a term which, while expressing the fact that all have hitherto proved unfossiliferous, leaves the question of their geological horizon quite open.

CHAPTER 5.—METAMORPHIC SERIES.

Tracts occupied by crystalline rocks.

The area occupied by the various forms of metamorphic rocks, comprising granite, syenite, gneiss, hornblend-schist, quartzite and other crystalline formations, is considerable, and consists mainly of three large detached tracts: 1, around Baitool; 2, west of Hurda, Nimawur and Hindia; 3, west of Bagh, comprising a considerable portion of Alleerajpoor and Chota Oodipoor. Besides these principal tracts, small outliers are exposed in several places.

Each tract a portion of a more extensive area.

Each of the three areas, as laid down upon the map, is but a portion of a more extensive region occupied by the crystalline rocks. From near Baitool they extend far to the eastward beyond Chindwara; the exposure near Hurda is but a portion of the great spread of metamorphics underlying the alluvium of the Nerbudda valley, while the surface of the country is continuously occupied in great measure by these beds from near Bagh to beyond Aboo and Neemuch, a very large portion of Rajpootana being covered by them.

Minute description unnecessary.

It is evident that, as the tracts comprised in the districts to which this Memoir refers are merely portions, and small portions, of extensive areas of the same formations, all general descriptions of the rocks included may best be deferred until those areas have been examined. The examination, moreover, of the crystalline rocks on the map now published was of the most cursory description, the principal object being merely to determine the absence of other formations. It is only necessary now to point out the peculiarities of the small portions which have been surveyed. For this purpose each tract requires a few remarks in detail.

1. Baitool metamorphic tract.

To the south this is bounded by the traps a few miles from Baitool; to the north it is covered on its edges by the Talchir

and Damuda formations of the Tawa valley. It extends to the west for about 30 miles from Baitool, the crystalline rocks being exposed irregularly in the valleys, whilst the hills are capped by sandstone and trap. Its eastern extension has not yet been surveyed.

A large portion of this area consists of highly granitoid rock; indeed in a portion of it the existence of granite is mentioned by Mr. J. G. Medlicott in his report and indicated on his map. But he remarks on the indistinctness of the boundaries and on the difficulty of separating the granitoid from the gneissoid varieties.

The examination of the small tract around Baitool which is comprised in the map, was so hurried that the general direction of the foliation can only be approximately inferred. It appeared to be nearly the same as in the Nerbudda valley to the north, about east-north-east to west-south-west.

Small patch of metamorphics near Salbuldee.

About 30 miles south-south-east of Baitool at the south base of the Gawilgurh range of hills, a very small exposure of metamorphic rocks occurs close to the village of Salbuldee. The beds are only traced for a mile or two and appear not to exceed a few hundred feet in breadth.

2. Hurda and Nimawur metamorphic tract.

This also is of no great extent. To the east it is covered by the gravels and clays of the Nerbudda valley, to the north and south by trap, to the west by the Vindhyans. A considerable portion of the intervening area even is occupied by the series next to be described.

A large proportion of the rocks are, here also, highly granitoid. The general strike is east-north-east—west-south-west, and the dip in general nearly vertical.

Small exposures in Dhar forest.

Two small exposures of granitoid rock were met with in the Dhar forest, one close to the village of Mirzapoor, the other a few miles further west.

Several inliers of metamorphic rocks associated with Bijawurs and cretaceous sandstones are met with east of Bagh. They are surrounded on all sides by trap.

3. Alleerajpoor and Chota Oodipoor tract.

This is a far more extensive and important region than the other two.

About Bagh the trap, which to the east covers the surface of the Nerbudda valley, has been cut away by denudation, and the underlying metamorphic rocks come to the surface. Along the Nerbudda itself and its immediate neighbourhood the traps still continue to the westward, but owing to their southerly dip, the metamorphics crop out from beneath them a few miles north of the river: the south boundary of the metamorphics running nearly east and west for 70 or 80 miles. It then turns slightly south, and soon after is lost beneath the alluvium of Guzerat, east of Baroda.

Extension to the north-west.

To the north-west only a few outliers of trap are met with, the country being believed to be mainly composed of metamorphic rocks; it has, however, not yet been surveyed, and almost all that is known of it is to be gathered from the papers of Dangerfield, Fraser, and one or two other observers.

Direction of foliation.

The metamorphic rocks of this region have a different general foliation-strike from that observed further east. It is extremely constant throughout a considerable tract as usual. Except to the west and near the southern boundary in places, it rarely varies much from north-west to south-east, its extreme limits being usually east-south-east and south-south-east to west-north-west and north-north-west, and it is constantly nearly vertical. In very large tracts the rock is so excessively granitoid that no foliation

Passage from granitic into gneissic rock.

can be seen, but occasionally in the midst of a highly granitoid tract a well foliated bed of limestone or hornblendic rock may be detected. This occasional

existence of foliation amongst the granites, the circumstance that no general distinction can be drawn between true granites and the more crystalline forms of the gneiss, the lamination of which proves its metamorphic origin, and the arrangement of the granite in lamellar masses, constantly parallel to the gneissoid foliation, tend to show that the distinction between the two is apparent rather than real, and that the granite is an original constituent of the crystalline rocks and not intrusive, but that in the course of metamorphism it has undergone greater alteration than the gneissose rock, and crystallization has become developed to so great an extent as to obliterate foliation. In treating of the Bijawur and Champaneer beds it will be necessary to show the manner in which they appear to pass into the gneiss, and the connection of the metamorphic foliation with the lines of cleavage will best be illustrated in the course of the same discussion.

Passages of Bijawur and Champaneer beds into metamorphic rocks.

Foliation of the gneiss.—All observers of the metamorphic rocks of Bengal, so far as I am aware, have considered the foliation of those beds to be in the planes of original bedding. The reason for so doing is that the mineral distinctions in the rocks, as between gneiss, hornblend-schist, and quartzite, (distinctions which involve a difference of chemical constitution, and which may, with fair probability, be referred to original differences in the materials composing the sedimentary rocks now metamorphosed), appear to take place along lines coinciding with those of the foliation. This is apparent also on a very small scale: it is no uncommon circumstance to see, within the breadth of a foot or two, successions of laminæ, quartzose, hornblendic, micaceous or felspathic, each of which may be traced for some yards. All appear to be lenticular, but the same is usually the case with fine alternations of different kinds of sediment amongst rocks of aqueous origin.

Reasons for supposing foliation of Bengal gneiss to be in the planes of original bedding.

It, of course, by no means follows that the same cause has influenced the direction of the foliation planes in Bengal and in the Nerbudda valley. The subject still requires some further study, and rather with the object of promoting such, than to express a strong opinion, it is well to point out a few circumstances which, in the Nerbudda valley, tend towards showing that the gneiss foliation there originated, not in bedding, but in cleavage.

Circumstances which tend towards a different conclusion in Nerbudda valley.

It has been already remarked that both the strike and dip of the lamination in the metamorphic rocks of the Nerbudda are remarkably constant over large areas. Both near Baitool and about Hurda and Nimawur the strike rarely diverges much from east-north-east to west-south-west, while in the large tract between Chota Oodipoor and Bagh, it is equally constant to a north-west—south-east, direction. In both cases it is generally vertical, and rarely dips at a lower angle than 70°. Nor is the constancy of the strike and dip by any means confined to the small area about Hurda, for the same is shown in Mr. J. G. Medlicott's map throughout the Nerbudda valley as far as Jubbulpoor, and in a MS. report by Mr. Mallet, on the country between Jubbulpoor and Burwai, the following sentence occurs: "The strike of foliation is pretty constant throughout the gneissic area, very seldom exceeding the limits of east and north-east; the usual strike is east 10°-25° north, the foliation being, where observable, always close to vertical. I observed a single doubtful exception * * * * * . *The bands of limestone and of schist invariably lie parallel with the foliation.*"

Remarkable constancy of strike and dip of foliation.

To the italicized portion reference will be made presently; the remark is important, because Mr. Mallet's work was entirely independent of that which forms the subject of this report, although he examined a portion of the same ground. The same remarks would not apply to the metamorphic rocks in all parts of India.

Parallelism of great features of the country to the foliation-strike.

Not only is the strike thus singularly constant, but to it are parallel all the great features of the country, the hill ranges, many of the trap dykes and all the principal faults.* Even the line of the Nerbudda valley itself is in the same direction. It is a curious circumstance moreover that this valley loses its peculiarly defined outline on the north side, and the scarp, which stretches almost uninterruptedly from north of the Sone and Nerbudda valleys near Sasseram in the valley of the Ganges to Bagh, ends at the spot where the direction of the gneiss lamination changes.

Difficulty of supposing foliation in planes of bedding.

Now, bearing in mind the persistent verticality of the gneiss, this constancy of strike would be a most abnormal circumstance if the foliation were in the original planes of the bedding. It would show that while the rocks had undergone such enormous disturbance that their originally horizontal beds had become vertical, that disturbance had nevertheless been so regular that their strike had never altered. This is certainly not usually the case with rocks which have undergone great disturbance. As a general rule, their direction is far from regular, and their dip in the last degree variable.

Characters of dip and strike of foliation those of planes of cleavage.

On the other hand, the constancy of the strike and the persistency of the high dip are characteristic properties of cleavage. The exceptions to the ruling direction are not more numerous than might fairly be expected to have arisen from the subsequent disturbance which has affected the region, and evidence of which is found in the Vindhyan and other later formations.

Parallelism of gneiss foliation to cleavage of Bijawurs.

This, however, is only one argument in favor of the foliation of the metamorphic rocks being due to cleavage. The most important remains. It is the perfect parallelism everywhere existing between the foliation of the gneiss and the cleavage lamination of the Bijawur beds.

* See Mr. J. G. Medlicott's report and map *passim*; M. G. S. I., Vol. II.

In the Hurda and Nimawur country the strike of the gneiss foliation is east north-east. In the Dhar forest the strike of the cleavage foliation of the Bijawur beds is the same. In the Bagh country the gneiss strikes nearly north-west—south-east, so does the cleavage of the Bijawurs, and in the latter instance it must be borne in mind that this is distinct slaty cleavage, and that in one spot at least it was clearly seen to cross the original bedding. Again, in the slates of the Champaneer beds, the cleavage is west-north-west—east-south-east, not differing greatly from the north-west—south-east lamination of the Ruttunmul and Chota Oodipoor gneiss.

Some points in favor of foliation being in planes of original bedding.

At the same time evidence in favor of the original bedding of the rocks having determined the direction of the foliation planes is by no means wanting. Bands of limestone and schist do, as stated by Mr. Mallet, most unquestionably coincide in direction with the foliation. In one instance especially, the band of limestone which stretches along the base of the hills south-east of Ruttunmul and north of Chandpoor, a band of great thickness, was traced for many miles, 10 or 12 at least, its direction throughout coinciding with that of the foliation observable in it. If this mass of limestone is not a bed, what can it be? Bands of granitoid rock, varying in mineral constitution, accompany it, and run parallel to it throughout. And this is not an isolated phenomenon. If it were it would be simple to suppose that in this instance the original bedding and cleavage coincided; but throughout the whole country, similar cases in which bands of peculiar mineral composition run parallel to the line of strike are certainly the rule, although without closer survey, it is impossible to say whether exceptions occur.

It is evident that much careful study must yet be devoted to these rocks in the field before their history can be cleared from obscurity.*

* The only suggestion I can make is that the cleavage was due to pressure acting upon nearly horizontal beds, and which crumpled them into a wave-like form, so that the strike of the constituent beds, thus bent in ridges like corrugated iron, may coincide generally with that of the cleavage, although the dip of the former is lower.

Chapter 6.—Bijawur Series.

Intermediate in character between metamorphics and Vindhyans.

Besides the granitoid and gneissoid metamorphic formations, there is another series of rocks largely developed in the western Nerbudda valley, which while less crystalline than the gneissic, and while occasionally showing scarcely any traces of alteration, is nevertheless in general much more metamorphosed than the Vindhyans and other stratified rocks of newer age. This formation had never previously in the Nerbudda valley been distinguished clearly from the true gneissic metamorphics, although its characters were partly pointed out by Mr. J. G. Medlicott in Vol. II of these Memoirs.

Peculiar rocks comprised.

The rocks to which these remarks refer were first met with in the course of the present survey, in the country between Nimawur and Chandgurh. They were again recognised in the Dhar forest, where they are exposed over a large area, and they were subsequently met with near Bagh and elsewhere. Two rocks, composing no small portion of their mass, are indeed so peculiar and characteristic that it would be impossible to pass them over without notice.

Laminated silicious limestone.

The first of these rocks is a very silicious limestone composed of fine alternating laminæ of carbonate of lime and quartz, the lime generally predominating in amount. This rock has a distinctly bedded appearance, which, however, is fallacious, for the regular succession of thin bands of quartz or lime-

Lamination not due to bedding.

stone which simulate stratification are in reality lines of lamination generally corresponding to original cleavage planes, and may be considered an incipient stage of gneissoid structure. This may be suspected (and was so) from the very great steadiness of dip and strike, the former at high angles, seen in these rocks. But far better evidence was obtained to prove that this structure was not due to the original planes of stratification. In some instances

In the Hurda and Nimawur country the strike of the gneiss foliation is east north-east. In the Dhar forest the strike of the cleavage foliation of the Bijawur beds is the same. In the Bagh country the gneiss strikes nearly north-west—south-east, so does the cleavage of the Bijawurs, and in the latter instance it must be borne in mind that this is distinct slaty cleavage, and that in one spot at least it was clearly seen to cross the original bedding. Again, in the slates of the Champaneer beds, the cleavage is west-north-west—east-south-east, not differing greatly from the north-west—south-east lamination of the Ruttunmul and Chota Oodipoor gneiss.

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Lamination not due to bedding.

stone which simulate stratification are [illegible] lines of lamination generally [illegible] nal cleavage planes, and may be considered [illegible] [illegible]re. This may be suspected [illegible] [illegible]ness of dip and strike, the former [illegible] [illegible] far better evidence [illegible] [illegible] due to the [illegible]

as on the Chota Tawa river near its confluence with the Nerbudda, and in the Kanyar river in the Dhar forest, the laminæ were found to be no longer plane, but concentric around a nucleus, and near Bagh the bedding was in more than one case traced across the direction of the lamination, the latter being parallel to the cleavage seen in the slates.

Jasper or hornstone breccia.

The other rock is equally striking. It is a massive breccia, the matrix of hornstone or jasper generally more or less red in colour, and containing angular fragments of white quartzite, sometimes apparently arranged in regular strata, but traversed in every direction by cracks filled with the jasper.

Prevalence of brecciation in Bijawurs.

Brecciation indeed is extremely common throughout all the beds of the series. In places where the limestone and quartzite join, masses of each are found enveloped by the other, as though the whole had been crushed and ground together. At the same time there appears reason for believing that the phenomenon is not confined to this series, but that it is occasionally manifested amongst the lower beds of the overlying Vindhyans.*

Other kinds of rock met with.

Besides these two kinds of rocks, sandstones, generally argillaceous and often brecciated, frequently with irregular quartzose layers and concretions, slates of various kinds, schists, not, however, very distinctly crystallized though completely laminated, and quartzites, are all of more or less frequent occurrence. Clay slate abounds in these rocks near Bagh. Traps also, much cleaved, but still bearing the appearance of interstratification with the other beds, are of occasional occurrence.

* For this observation I am indebted to my colleague Mr. Mallet as detailed elsewhere. I had not myself clearly traced the breccias in the Vindhyan beds, but although I saw that some breccias, especially those near Andhari Bagh in the Dhar forest, could not clearly be assigned to the Bijawurs, I hesitated to consider them Vindhyans. Mr. Mallet's explanation of the Tawa and Pullasee sections has shown that the Vindhyan beds are probably occasionally brecciated, and as my observations of matters of fact as recorded in my field notes coincide with Mr. Mallet's, I think that he is right in this opinion.

Nerbudda valley beds identical with typical Bijawurs.

On the north of the Vindhyan area, two great series of rocks were described by Mr. H. B. Medlicott in 1859 as intervening between the Vindhyans and the gneiss. Both of these, the Semri or sub-Kymore* and the Bijawurs, contain breccias and limestones, and both have characters in common with the breccias, limestones and other associated rocks of the Nerbudda. But quite recently, Mr. Mallet (who has for many years past been engaged upon the Vindhyan rocks and their associates in Bundelcund and the Sone and Nerbudda valleys, and who has examined the rocks of Chandgurh, the Dhar forest, &c.), has had an opportunity of re-examining Mr. Medlicott's typical area, and has ascertained, he believes without any possibility of error, that the breccias and limestones of the Western Nerbudda are the equivalents of Mr. Medlicott's Bijawur series. This name therefore being that first applied as a distinctive title to these rocks will be employed in describing them in the present report.†

Places where Bijawurs occur in Western Nerbudda valley.

In the tract of country east of Chandgurh and the Little Tawa, these rocks have been entirely mapped and separated from the metamorphics by Mr. Mallet. It is in the western part of the area alone that their boundaries have been determined by the Bombay party of the Survey in detail. West of Chandgurh these rocks appear in the following places, all north of the Nerbudda :—

1. In the Dhâr forest, where they cover a very considerable area; metamorphics only being seen in two or three isolated exposures which are on the verge of the trap country to the north.

2. Near Burwai, in the valley of the Chorul. This field of Bijawurs is only separated from the last by a strip of Vindhyans and trap.

* These are now classed by Mr. Medlicott as a lower sub-division of the great Vindhyan series.

† It is necessary to refer to my colleague's unpublished reports to explain the nomenclature I have adopted. The subject will be treated at length by Mr. Mallet.

marked cleavage [illegible] former [illegible] jasper [illegible] is also certain [illegible] scarcely been moved [illegible] situ (whether [illegible] immaterial), [illegible] cracks, would account [illegible] the shattering process must have been [illegible] tion have taken place after each [illegible] latter to have been [illegible] many cases so utterly irregular as it is.

Connection between Bijawurs and metamorphics.

The connection between the Bijawurs and the metamorphics is one of no small interest. Although by no means clearly made out the impression produced by the rather rapid survey which was made of the country was that the two passed into each other in all probability. There was only one spot where this appeared to take place, *viz.*, north-east of Johut, and even there it is possible that faults were overlooked, but the complete representation of beds in one series by corresponding rocks in the other, foliated limestone by laminated crystalline marble, hornstone by quartzite, slate by felspathic schist, ferruginous breccia by magnetic iron and quartz in laminæ, trap by hornblend schist, &c., is in favor of the identity of the two. There is even frequently more exact resemblance traceable than is due to the mere occurrence of beds of the same composition. Thus the peculiar limestone with thin laminæ of quartz in the Bijawurs is represented by a precisely similar rock in the metamorphics, only differing in the carbonate of lime being more crystalline. In any case it is perfectly clear from the remarkable parallelism already pointed out between the lamination of the gneiss and the cleavage foliation of the Bijawurs that the latter series existed and had undergone cleavage before the former were metamorphosed, for

3. At Bagh a peculiar triangular tract is occupied by this series.

4. At Jobut, where a roundish patch occurs. The rocks here are perhaps less characteristic than elsewhere, but there appears little reason to doubt their belonging to the same series.

Association of granitoid rocks near Jobut.

In the Jobut patch alone was any association of plutonic rocks remarked. Here in two cases granitoid rock was found associated with the Bijawurs, in one case being distinctly intercalated in the beds. It is, however, worthy of notice that the granitoid rock in each case was of a different variety from any prevalent in the metamorphics. In one instance where the granite was distinctly seen intercalated between bands of Bijawurs, it was a coarse ternary form; in the other, where masses of granitoid rock were found in the centre of the district occupied by the Bijawurs, they were composed of felspar and epidote, the latter partly in small veins, partly disseminated and passing into serpentine.

Obscurity of bedding. No sequence can be traced.

Nothing like sequence could be made out in the Bijawurs; as has been already stated, the bedding is very obscure as a rule, so much so that it is impossible to ascertain the relations of different beds to each other. In general the bedding can be fairly seen in the quartzites and hornstones, but it is completely obscured by cleavage lamination in the limestones, slates and other rocks.* In some places, as at Jobut, it seems to be very little disturbed; in others as near Bagh, it is greatly contorted.

Origin of brecciation.

The abundance of brecciation in the Bijawurs is very remarkable, and may possibly be connected with the great lateral pressure to which the rock has been subjected, and to which its well

* In examining the Bijawurs great caution must be used in admitting any apparent case of unconformity which may be met with. The bedded uncleaved quartzite or hornstone, dipping at no great angle to the horizon, often rests upon vertically laminated limestones or schist, and if their foliation be not carefully distinguished as such, the observer is very likely to suppose that it is bedding, and that the quartzite or hornstone is resting upon the upturned and denuded edges of the older rocks, while in reality the two may be quite conformable. Instances of this kind were not unfrequent about Bagh and Jobut.

marked cleavage is originally due. It is very clear that the breccias are formed of fragments of a pre-existing quartzose rock cemented together by jasper, a form of silica usually supposed to be deposited from water, and it is also certain that, in some instances, the fragments of the quartzite have scarcely been moved from their original position, so that shattering in situ (whether by a sudden shock or by continued unequal pressure is immaterial), and the deposition of silica from solution in water in the cracks, would account for the phenomena. But if this be the explanation, the shattering process must have been frequently repeated, and the infiltration have taken place after each production of cracks to have caused the latter to have been so wide, and the position of the angular fragments in many cases so utterly irregular as it is.

Connection between Bijawurs and metamorphics.

The connection between the Bijawurs and the metamorphics is one of no small interest. Although by no means clearly made out the impression produced by the rather rapid survey which was made of the country was that the two passed into each other in all probability. There was only one spot where this appeared to take place, *viz.*, north-east of Jobut, and even there it is possible that faults were overlooked, but the complete representation of beds in one series by corresponding rocks in the other, foliated limestone by laminated crystalline marble, hornstone by quartzite, slate by felspathic schist, ferruginous breccia by magnetic iron and quartz in laminæ, trap by hornblend schist, &c., is in favor of the identity of the two. There is even frequently more exact resemblance traceable than is due to the mere occurrence of beds of the same composition. Thus the peculiar limestone with thin laminæ of quartz in the Bijawurs is represented by a precisely similar rock in the metamorphics, only differing in the carbonate of lime being more crystalline. In any case it is perfectly clear from the remarkable parallelism already pointed out between the lamination of the gneiss and the cleavage foliation of the Bijawurs that the latter series existed and had undergone cleavage before the former were metamorphosed, for

we can hardly suppose that in two different but neighbouring districts two distinct cleavages should have been produced in one set of rocks, each exactly parallel to the previously existing gneiss lamination in the district. It is far more probable that they would be parallel to each other.

Metamorphics may be partly older than Bijawurs, partly identical.

At the same time it is quite possible that the metamorphics may be in great part at least an older formation than the Bijawurs and even unconformable, and yet that the Bijawurs may have been locally metamorphosed. All these questions await further explanation. They are mentioned here because in the examination of these beds they have frequently been presented by the various phenomena observed, and even this imperfect discussion may be of aid to others similarly engaged elsewhere, but who observe other characters of the rocks or see similar characters under different circumstances.

Relations of Bijawurs and Vindhyans.

The relations between the Bijawurs and the Vindhyans are very simple, *viz.*, utter unconformity.

CHAPTER 7.—CHAMPANEER GROUP.

Locality.

In the extreme north-west of the area mapped, a small tract, about 30 miles east of Baroda, consists of beds which, although somewhat similar in general character and state of semi-metamorphism to the Bijawurs, differ so greatly in their mineral composition that it appears probable they must belong to a distinct group of rocks. They do not contain any of the rocks so characteristic of the Bijawur series while their own marked beds are wanting in that. It is by no means clear whether, if distinct, they are higher or lower in the general series; they vary greatly in the extent to which they are metamorphosed, and they are, in the area examined, entirely isolated: very probably they do not differ greatly in age from the Bijawurs.

Difference from Bijawurs.

Area occupied.

The area occupied by these beds extends for about 20 miles to the east from Powagurh hill, and for 7 or 8 miles to the south from Champaneer, at the north-east base of the hill. To the north they stretch for a considerable distance, but have not been examined. There is also a small tract of hilly country a few miles further south, which appears to consist of them. As it does not appear at all certain whether they can be referred to any one of the systems of rocks hitherto described as intervening between the metamorphics and the Vindhyans in Central India, it appears best to give them a temporary and local name, and that of the old town of Champaneer, the former capital of the Mahommedan Kingdom of Guzerat, appears best suited for the purpose.

Name.

Rocks composing the group: quartzite.

The principal constituent rock of the Champaneer beds is quartzite or quartzite sandstone, very similar in character to rocks which occur both in the Bijawurs and the metamorphics. The other beds are mostly slates, conglomerates, and limestones, ferruginous bands occasionally occurring. Some of the limestones are highly crystalline; in one place near Kudwal they were found to contain actinolite; in other places, as near Soorajpoor, they were quite unaltered. All the rocks susceptible of cleavage are highly cleaved, the planes striking about west 10°-20° north in general. Some of the slate appears to be so fissile that it might probably be made available for roofing.

Conglomerate.

The conglomerates are perhaps the most distinctive beds in the group. They are well seen about Jhubban on the road between Soorajpoor and Jumbooghora. The matrix is in general a coarse gritty sandstone, containing pebbles and boulders often a foot in diameter, and occasionally more (one was measured which amounted to 3 feet), and consisting of granite, quartzite, talcose slate, and crystalline limestone. The talcose slate of which some of the pebbles are composed is scarcely more metamorphosed than the Champaneer beds themselves. The quartzite boulders are the largest. The limestone

pebbles are very numerous, and as they are dissolved away on the surface by exposure to the weather, the hollows which contained them remain empty, and give a peculiar vesicular appearance to the rock. Some of the limestones of the pebbles contain silicious laminæ as in the limestones of the Bijawurs, but the rock in this case is more crystalline. It rather resembles the limestone in the metamorphics east of Kanas. The cleavage, which is characteristic of the Champaneer beds throughout, is frequently apparent in these pebbles, though it is but rarely distinguishable in the sandy matrix; none of the pebbles are typically Bijawur.

Breccia conglomerate near Anandpoor.

At one place near Anandpoor the matrix of the conglomerate appeared to be a perfect breccia, a mixture of angular fragments of black slaty silicious rock and coarse sandstone, both containing pebbles. This was near the junction of the conglomerate with slaty beds, the latter apparently the newer. The rocks appeared to have been much crushed; they look as if angular fragments of slate had become mixed with sandstone, and then all reconsolidated. The granite and quartzite pebbles, however, exhibit no signs of any violence.

Sequence of beds.

Very little can be ascertained of the sequence of the beds. The slates, limestones and quartzites of Soorajpoor are evidently high in the series; they appear to rest upon the conglomerates of Jhubban and these again upon the quartzites of Narookot and Dandiapoora. Judging from the extent of alteration too, the Soorajpoor beds are high in the group. But no base is seen, unless the quartzites of the southern patch rest upon granite about Manikpoor. These quartzites much resemble those of Narookot, &c.

Passage into metamorphics.

Reference has already been made to the apparent passage of Bijawurs into metamorphics; in the case of the Champaneer beds the appearances are much stronger, especially along the southern boundary; so much so indeed

that it is frequently almost impossible to determine exactly where that boundary should be drawn. Within the tract occupied by the metamorphic rocks, quartzites which have in no way the appearance of outliers occur in several places, as near Meerwania, and again west of Jumbooghora. In the latter case a true conglomerate containing large rolled pebbles of quartzite, &c., and very similar to the conglomerate already described as occurring a little further to the north-west, is found amongst the metamorphic rocks. The same apparent passage occurs south of Soorajpoor, the Champaneer beds being more crystalline near the boundary. There is, of course, the possibility of faults accounting to a great extent for these apparent passages, and when rocks do not differ greatly in mineral composition, apparent cases of transition are very likely to occur, but still there is, in places, an apparent gradual change, both along the line of strike and across it, from Champaneer beds into metamorphics.

CHAPTER 8.—VINDHYAN SERIES.

Small portion of Vindhyan area included.

Only the extreme south-west corner of the immense tract covered by this formation is included in the present map.*

The principal character of the Vindhyans of Bhopal and the Dhar forest is the prevalence of a very compact deep red or purplish rock, in which the original texture of a sandstone has almost entirely disappeared. It is purely quartzose, translucent, and has at times almost the appearance of being crystalline quartzite. On its fracture it has the vitreous

* As the whole of the Vindhyans will shortly be described at length by Mr. Mallet, who has had opportunities of studying them throughout their area, and who has examined the small exposures of them comprised in the Western Nerbudda country, it is unnecessary for me to do more than indicate their general characters in the briefest manner, especially as neither Mr. Wynne nor myself had ever seen the Vindhyans before we were engaged in mapping this tract.

appearance and conchoidal form of quartz. It is clearly intermediate between a quartzite and a sandstone.*

Conglomerate.

Conglomeritic bands are not rare. The bedding is invariably well marked, oblique lamination being rare. The separate beds are of a small thickness in general, and the rock is occasionally flaggy. Conglomerate, containing pebbles of metamorphics and other rocks of no great size, is not unfrequent. Rippling abounds on all the surfaces. In a few places, especially about Gunnoorgurh near Hoshungabad and the villages of Dharee, and Paimgurh in the Dhar forest, softer and more shaly beds occur, grey or greenish in colour. These are higher in the series, and have been shown by Mr. Mallet to belong in part at least to the 'Bundair' division of the Vindhyans, while the quartzite sandstones at the base of the series represent the 'Rewah' beds of Bundelcund.

Shaly beds.

Relations to Bijawurs.

The Vindhyans rest quite unconformably upon the Bijawurs, and contain rolled fragments of the latter in their conglomerates.

Thickness of series in Dhar forest.

The thickness of the Vindhyans in the Dhar forest must be very great, but it is very difficult to estimate it exactly, as faults occur : of the lower beds alone, in the section from Pullasee to west of Sakarghât, scarcely less than 7,500 feet can be exposed. This is calculating the average dip at 12°, and allowing for one small roll. The estimate is probably below the truth, and as there are at least 2,000 feet above those exposed in the Sakarghât section seen about Paimgurh and Dharee, the whole thickness of Vindhyans in the Dhar forest can scarcely be much less than 10,000 feet.

* I should almost be disposed to call it a quartzite, but as it passes into sandstone in places, and the Vindhyans in general are perfectly unaltered rocks, this might involve the idea of their mineral condition being different from what it is.

CHAPTER 9.—CRETACEOUS SERIES—BAGH BEDS, AND MAHADEVA GROUP.

Absence of great plant-bearing series of Bengal and Central India in Western Nerbudda valley, &c.

Although it is highly probable, as will be shown presently, that some rocks belonging to an intermediate formation have been classed with the Mahadeva series or its equivalents on the map in the neighbourhood of Baitool, no formation whatever appears to intervene in the lower Nerbudda valley between the old unfossiliferous Vindhyans and the great trappean series, except the sandstones and limestones of Burwai, Bagh, Alleerajpoor, the Deva Nuddee, &c. No trace of Talchirs, Damudas, Panchets or other members of the great plant-bearing series of Bengal and the Central Provinces has been met with west of Hoshungabad.

Name of Bagh beds not well chosen.

The history of the rocks of Bagh has already been given, together with the reasons for their assignment to the cretaceous series, in describing the labours of previous observers. The name employed is perhaps not so well chosen as might be wished, for the town of Bagh itself does not rest upon the beds, nor are they especially developed in its immediate neighbourhood; two of the most characteristic kinds of rock, the so called 'coralline limestone,' and the argillaceous limestone from which the fossils have chiefly been procured, being both absent and, as has been shown, confusion has already arisen from the name. Still the term has now been used too long, and is too generally known to be easily changed, and the objections to its retention are not strong enough to justify an attempt at altering it.

Area occupied by Bagh beds.

The Bagh beds are found occupying a considerable tract between Chota Oodipoor and Baroda, extending westward to within 30 miles of the latter station; throughout this country they form a fringe, which is rarely wanting along the edge of the traps. It is not, however, quite persistent; occasionally the traps rest immediately upon the metamorphic rocks. Besides this fringe, many inliers, of every possible size, from a few yards

square to 80 square miles, are met with scattered throughout the trap area to the south, as far as the Nerbudda, and in one instance to the south of that river, upon its tributary the Deva, these inliers are exposed in a very peculiar manner, which will be described in treating of the tract in question. Outliers upon the metamorphic rocks to the north of the trap boundary are, on the other hand, rare. One, however, is met with upon the top of Ruttunmul hill at a considerable distance from any traps.

To the eastward, about Allee, the same fringe of the cretaceous beds is met with, but north of this, the traps of Malwa cover the ground to the north of Rajpoor, and although a similar border of cretaceous rocks is found along their edge, it is narrower, the beds being much thinner. The traps gradually cover the whole valley about Bagh, and near this point, between Bagh and Rajpoor, are some very large tracts of cretaceous beds. Further to the eastward, within the trap area, are several inliers of Metamorphics and Bijawurs surrounded by the cretaceous rocks more or less completely; these continue nearly as far as Mandoo. The Bagh beds have thus been traced, almost continuously, for about 100 miles, when a break occurs; trap alone occupying the valley from a little east of Mandoo till close to Burwai, a distance of about 50 miles. At Burwai the older rocks reappear from beneath the trap, and around their edge, for a considerable distance, conglomerates and sandstones occur, which there can be very little hesitation in referring to the Bagh beds. To the extreme extent of these rocks to the eastward it will be necessary to refer again when treating of their connexion with the Mahadevas.

Mineral character at Bagh.

In mineral character there is great variation. At Bagh itself the section has been described more or less accurately by several previous observers. It consists of 15 to 20 feet of unfossiliferous or nearly unfossiliferous nodular limestone, resting upon sandstones, fine and coarse, white to purple in colour, and conglomerate. Some of the sandstone beds are more or less argillaceous

or shaley and occasionally calcareous. The only fossils are a few bivalves too ill preserved for identification. These sandstones are about 80 to 100 feet thick. As before noticed, *none of the Bagh fossils have been obtained from these rocks.*

Prevalence of limestone in topmost beds.

This Bagh section, although very imperfect, exemplifies one character of the Bagh beds, which is pretty constant, the general tendency to a prevalence of limestone, more or less pure, towards the top and of sandstone below. To the westward the mass of the rocks consist of coarse sandstones and conglomerates, frequently calcareous above, becoming at times a gritty limestone, or else capped by shales, more or less calcareous. In the most westwardly portion exposed, where the development of the beds generally is greater than elsewhere, these shales sometimes attain a great thickness. In the Deva valley amongst the Rajpeepla hills, they attain to as much as 500 feet in one place near Doomkhul. Beneath them are coarse compact gritty sandstones of at least an equal thickness. Where the rocks are thin as at Ruttunmul and near Kanas only conglomerate and coarse sandstone is met with. These conglomerates and sandstones are not only calcareous, but frequently also cherty towards the top, that is, near their junction with the traps. Masses of chert (noncrystalline impure silica), frequently as much as 2 or 3 feet in diameter, occur in them. The same is sometimes but less frequently the case with the uppermost shales.

West of Bagh.

East of Bagh—coralline limestone.

East of Bagh a change takes place in these beds, and here alone is found the "coralline limestone," which from its employment in the now-ruined buildings of Mandoo first attracted notice to these strata. This limestone is red or yellow in colour (the former colour apparently being the result of exposure); it consists mainly of fragments of *bryozoa*, shells, &c., which are not easily recognised on a fresh surface, but weather out upon exposed blocks. The fresh surface has a somewhat granular mottled appearance, which is

highly characteristic. In many places the bed exhibits oblique lamination, showing that it accumulated in a current. Beneath it, at Cherakhan, twenty-two miles east of Bagh, and one or two other places in the neighbourhood, is the bed, an impure argillaceous limestone, from which all the fossils of this group which have hitherto been described were obtained; this again rests upon unfossiliferous nodular limestone, similar to that which forms the top of the beds at Bagh. Beneath this there is probably sandstone. Some red marl, with calcareous concretions and sandstone a little further east, is found resting upon the limestone, but it appears to be local.

Fossiliferous limestone of Cherakhan.

The general section of the Bagh beds about Cherakhan appears to be

Coralline limestone	... ...	10 to 20 feet.
Fossiliferous argillaceous limestone abounding in Echinoderms *(Hemiaster)*	...	about 10 feet.
Unfossiliferous nodular limestone	...	20 feet.
Sandstone and conglomerate	...	20 feet.

Further to the eastward, the conglomerates and sandstones, which reappear along the edges of the Dhar forest, are similar to those of Ruttunmul and Kanas. The limestones are wanting, or represented by a calcareous gritty band at the top.

Rocks further east.

From the above remarks it will be apparent that these beds vary greatly both in mineral character and in thickness. The latter, however, appears to change according to a well marked rule, and to increase towards the south. Along the northern portion of the present map, the Bagh beds never exceed about 60 feet, and they frequently appear to thin out almost entirely. To the southward, they even amount to 1,000 feet in the Deva valley, and their base is not seen. At Bagh they are about 100 feet thick, and they appear to be still more a little to the south, while 10 or 12 miles to the north, near Tanda, they are represented by from

Increase in thickness towards the south.

10 to 20 feet of limestone and sandstone, or are entirely wanting. That this difference in thickness is not due to subsequent denudation appears pretty plainly from the uppermost bed being constantly the same, a calcareous and frequently fossiliferous band, in places where the thickness differs greatly.

Doubts as to relations of sandstone.

Before quitting this subject it may be as well to notice that there is a bare possibility that the massive sandstone does not belong to the same formation as the overlying limestone and shale which alone are fossiliferous. But its great constancy, and the apparently perfect conformity of the two groups, render it most probable that they both belong to the same series. At the same time the sandstone may represent some of the formations of Central India. The thick sandstones of the Deva Nuddi have some slight resemblance to the Mahadevas. So far as the study of them has hitherto proceeded however they appear to form an integral portion of the same group as the limestones and shales. As will be seen presently this by no means renders it impossible that they represent the Mahadevas.

Fossils.

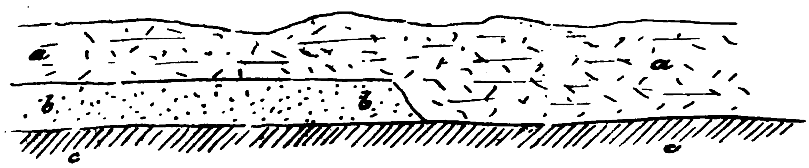
The sandstone appears to be entirely unfossiliferous; the principal organic remains in the argillaceous limestone are Echinoderms, especially *Hemiaster*, and lamellibranchiate bivalves, amongst which *Pecten 4-costatus* is prominent and abundant. A small *Rhynconella* also is very common. *Bryozoa* of several kinds are the most conspicuous organisms in the coralline limestone. Some of these fossils are occasionally met with further to the west, but the only organic remains which are at all common near Kawat and the Deva are some well marked species of *Ostrea* and shark's teeth. It is not impossible that this difference, together with the great change in the mineral character of the beds, indicates a difference in the conditions of the area in which they were deposited. There can be no question but

the limestone near Bagh is marine, while the calcareous shales to the west may be estuarine.

Relations to underlying beds and to the overlying traps.

The Bagh beds are, of course, utterly unconformable to the ancient formations upon which they rest. Their relations to the overlying traps are somewhat peculiar. Throughout large areas they have the appearance of perfect conformity, and even where the cretaceous beds are very thin, not exceeding 30 to 40 feet in thickness, they often appear for miles without a break at the base of the traps. But in general there are breaks every here and there, and in other cases only patches of the cretaceous beds are met with intervening, the traps generally resting directly upon the gneissose or other older series. This latter case which may be seen at Tanda north of Bagh is very possibly due to the accumulation of the Bagh beds in hollows; it is far from impossible that they never existed as a continuous bed to the northward. But numerous instances are met with, and will be found mentioned in the subsequent pages, in which the cretaceous rocks had unmistakeably undergone denudation before the deposition of the traps. Sections of this kind are met with (Fig. 1), and in such the abruptness of the denudation is very

Fig. 1.



a, Trap: *b*, Bagh-beds: *c*, Metamorphic rocks.

marked. It is precisely that which would be caused by a stream. Its excessive irregularity indeed is typical of subaërial denudation, and the circumstance of no general removal of the cretaceous beds having taken place seems to show that the rocks of Bagh, although of marine origin, had not undergone marine denudation before the traps covered them.

Greater unconformity between Bagh beds and traps to the westward.

The above exhibits the general state of the case in the neighbourhood of Bagh and Rajpoor. To the westward there is in places, an appearance of greater denudation having taken place. An instance will be described in the following pages south of Kawat, and another on the east side of the Deva inlier, where the traps appear to have accumulated against a previously denuded cliff of cretaceous beds. It is true that both instances may be due to faulting, but, for reasons which will be explained, this appears less probable than the hyphothesis of previous denudation Nevertheless in the immediate neighbourhood, in both cases, the traps rest, to all appearance conformably, upon the undenuded surface of the Bagh beds, shown to be undenuded by the persistence of the same bed beneath the bottommost flow of trap, and in these and every other case, the very close parallelism, *i. e.*, the general conformity in dip of the two series, is remarkable. Although considerable disturbance has taken place (especially south of Kawat), the greater portion at least is palpably of post-trappean date. In one or two local cases the Bagh beds had been apparently disturbed in pre-trappean times, but such instances are very rare.

Denudation of Bagh beds in pre-trappean times subaërial.

Even where the greatest amount of denudation has taken place, it presents no appearance inconsistent with the probability of its having been subaërial. It is always irregular, such as has left the surface in hills and valleys. It is always local, never general. Thus, even in this instance, we have strong evidence that the outpouring of the traps, even when they rest on unquestionably marine beds, was in itself subaërial, and not, as some writers have supposed, submarine.

Absence of great geological break between Bagh beds and traps.

To sum up, the traps rest nearly conformably upon a locally denuded surface of the cretaceous beds, the two series exhibiting general conformity. There is therefore no evidence of a great geological break between them. It should be added that similar local denudation has taken place between

the different trap flows, and an instance will be shown where, south of Kawat, one flow of trap covers a bed of rounded pebbles, very many of which have been derived from previous trap flows, all accumulated in a hollow which to all appearance has been formed by denudation in the interval between two successive eruptions. We have thus in the trappean series a break of a similar character to that which is seen at its base between its lowest members and the Bagh beds. It is perhaps wrong to conclude that the Bagh beds and the traps form one series, and therefore that the lowest traps, at least, are of middle cretaceous age, but it appears difficult to believe that they can be much newer, and highly improbable that they are of so late a date as eocene. This subject has already been treated in an earlier paper. (See Memoirs Vol. VI, pages 158, 159).

Relations of Bagh beds to Mahadevas.

It remains to trace out such connexions as may exist between the Bagh beds and the great formations to the eastward. All the beds older than the Mahadevas, the Rajmahals, Panchets and Damudas, have been shown by their fossils to be of pre-cretaceous age; but of the age of the Mahadevas nothing has with certainty been determined. They have been referred alternately to tertiary and cretaceous periods, but always on avowedly imperfect evidence.*

* The latest opinion on this subject is that expressed by Mr. Hislop in the Journal of the Bombay Branch of the Royal Asiatic Society Vol. VI, p. 200. He there considers the Mahadeva cretaceous, because "it underlies the Takli series, which is situated at the very base of the eocene," and because "similar sandstone with stems rests on the lower cretaceous rocks of Southern India." This passage contains several errors. In the first place the beds near Nagpoor, to which Mr. Hislop alludes under the name of Mahadeva, and which I have recently been able to examine, do not belong to that group, but are interstratified with the beds containing *glossopteris*, which are certainly not newer than the Trias. Then the "Takli series", or intertrappean of Nagpoor, as I have shown, are more probably cretaceous than eocene, and the sandstone with stems resting on the upper (not lower) cretaceous beds of South India has been shown to be probably tertiary. Nevertheless Mr. Hislop's conclusion is very probably correct, although more recent researches have shown that his data required modification.

Before entering into this subject, a word or two is necessary as to the rocks colored as Mahadeva upon the present map.

Area occupied by Mahadevas in present map.

These are found exposed whenever the traps have been cut through by denudation to the west and south-west of Baitool. They extend for a considerable distance down the deep gorge cut by the Taptee, and are found in several valleys to the north of that river. A sharp southwardly dip of the traps takes the base of that series far beneath the surface south of the Taptee, but along the south scarp of the Gawilgurh hills the traps turn up again, and a considerable thickness of sandstone is exposed beneath them on the flank of the hills north-west of Ellichpoor.

Beds near Ellichpoor.

The beds thus exposed consist near Ellichpoor at the top of calcareous grits and conglomerates or gritty limestones, of a grey colour abounding in chert, and precisely similar in all respects to the uppermost beds of the cretaceous rocks of Bagh and Alleerajpoor. Beneath these are coarse gritty sandstones, white or brownish in colour, occasionally conglomeritic, and very massive. Ferruginous bands are common, and also beds of argillaceous sandstone, white, lilac, and sometimes deep red in colour.

Near Baitool.

Further to the north, in the Taptee valley and near Baitool, the bed beneath the trap is more frequently a conglomerate, precisely similar to that met with in the Dhar forest. But occasionally sandstones and clays similar to those of Ellichpoor are met with.

Some of the Ellichpoor beds probably older.

At the time that the survey was made the whole of these sandstones, conglomerates, &c., were supposed to belong to one system, and were all classed as Mahadevas. But a subsequent examination of the country around Nagpoor has shown that the rocks there occurring and hitherto supposed to be Damudas differ greatly from the true Damudas in mineral character, and at the same time resemble the beds of Ellichpoor. It is therefore highly probable that near Ellichpoor, only the calcareous beds immediately below the traps

should be considered as representing the conglomerates of the upper Taptee valley. Very possibly some of the beds to the north of the Taptee should also be referred to the same series as the *Glossopteris* beds of Nagpoor. This is especially the case with the beds seen in the valley near Khattapani, the great vertical extent and disturbance exhibited by which and their apparent unconformity to the traps were noted at the time of the survey as showing them to be probably different from the usual infra-trappean sandstones and conglomerates. These latter from a thin band, rarely, if ever, exceeding 100 feet at the base of the traps, which appear to rest quite conformably upon them.

Relations of Lameta and Bagh beds.

Another connexion which has been traced out during the examination of the Nagpoor country is that between the Lameta beds of Jubbulpoor and these sub-trappean rocks. The Lameta beds* chiefly consist of—

1. Gritty and cherty limestone;
2. Nodular limestone;
3. Loosely aggregated greenish sandstone;
4. Argillaceous beds, purplish or greenish, arenaceous or marly;

the gritty and cherty limestone being by far the most typical and widely spread member of the group. This has been traced at intervals from Jubbulpoor to considerably south of Nagpoor, and there can be scarcely a doubt that it is identical with the subtrappean limestone of Ellichpoor. A bed which cannot be distinguished from it mineralogically is also met with frequently, interstratified with the traps, between Jubbulpoor and Nagpoor and in the neighbourhood of the latter.

This is not the only point of connexion of the Lametas with the Bagh beds. The nodular earthy limestone at Lameta ghât which there underlies the gritty and cherty limestone is very similar in appearance to the nodular limestone of Bagh and Cherakhan. Sandstone in both cases when present appears to be a lower formation in the same group.†

* See Mem. Geol. Surv., Ind., Vol. II, p. 196.

† Compare Mr. J. G. Medlicott's description of the Lameta beds at p. 197, Vol. II, of these Memoirs.

The Lameta beds are considered by Mr. J. G. Medlicott as probably replacing the Mahadevas to the eastward. To the westward the last representatives of the great Mahadeva sandstones and conglomerates of the Puchmurry hills occur at Lokurtullai, south of Hoshungabad, on the Morun River, where between 100 and 200 feet of coarse conglomerate, resting upon sandstone, is seen intervening between the traps and the Damudas. These conglomerates are remarkably similar in appearance both to those just mentioned as occurring below the trap in the neighbourhood of the Taptee, south-west of Baitool, and also to the rocks already mentioned, which are believed to represent the Bagh beds in the Dhar forest.

Bagh beds near Burwai.

To return to these latter : The Bagh beds proper are concealed by trap, as already mentioned, south-west of Mandoo. Close to Burwai a few irregular patches of sandstone and conglomerate and occasionally of limestone occur. In the latter, in one place, fragmentary marine shells were met with, one of which appeared to be a portion of an *ammonite*, a second a *rhynconella*. These calcareous beds certainly belong to the Bagh group, and there appears very little doubt but that the sandstone and conglomerate is also identical with that of Bagh which it resembles in mineral character.

Near Poonassa.

The sandstones and conglomerates are traced for some distance along the northern boundary of the Dhar forest. To the south they are less prevalent, but representatives of them occur about 2 miles west of Poonassa and just north of Bhorla. They are conglomerates precisely similar to those north-east of Burwai, and also closely resembling those of Lokurtullai on the Morun. In the neighbourhood west of the village of Bhorla and apparently overlying the conglomerate nodular and massive grey limestone with chert and containing fragmentary shells, is met with. At Bhorla tank is some hardened porcelain clay. The relations of these beds to each other is somewhat obscure, the ground being much covered by alluvium. There

can, however, be but little doubt that the conglomerates are identical with those of the Dhar forest, and there cannot be much doubt of their identification with the similar beds at Lokurtullai, while the limestone appears equally clearly to represent that of the Ellichpoor beds and probably the uppermost Bagh beds. It should be added that similar limestone occurs beneath the trap close to the smaller Tawa river about fifteen miles east of Poonassa, and that the distance from Poonassa to Lokurtullai is about seventy miles, the whole intervening distance being occupied by trap.

Summary of relations.

Thus it will be seen that a connexion has been traced out between the sandstones of Bagh and the conglomerates of the Puchmurry hills, and also between the marine limestone of Bagh and the freshwater limestone of the Lametas. Further researches may be necessary to establish this correlation, but it appears to rest on strong evidence.

One circumstance should be borne in mind: The traps are represented by Mr. J. G. Medlicott to be quite unconformable upon the Mahadevas. They appear, on the other hand, to be quite conformable to the Lametas. To the Bagh beds they have been shown to be generally approximately conformable, but with marked local unconformity. It is possible that the Lametas may be rather newer, or that the base of the traps to the eastward may be rather older. But the greater unconformity shown between the traps and the Mahadevas may be due to an interval between them represented by the limestones of Bagh.

Origin of Cherts in uppermost Bagh beds.

It is also highly probable that the cherty masses so frequently alluded to as characteristic of the uppermost beds of the Lameta and Bagh beds are due to infiltration of water containing silica from the overlying traps; to the same infiltration which has deposited agate and quartz so abundantly in the cavities of the traps themselves. This appears not unlikely, but where sandstones of a different age underlie the trap at Nagpoor nothing of the kind

occurs, although the beds are generally hardened, probably through infiltration, so that the mode of occurrence of silica in the Lameta and Bagh beds appears characteristic. It might even be suggested that the lime is also due to infiltration, but the latter is very improbable, carbonate of lime being a rare mineral in the traps, and the subtrappean beds being sometimes almost pure limestone totally devoid of crystallization. Had the carbonate of lime been derived from the overlying traps, it would certainly have been deposited in a crystalline form, and probably in veins and nests not uniformly throughout the mass of the rock.

CHAPTER 10.—DECCAN AND MALWA TRAPS.

Principal characters and relations previously described.

The great volcanic series in general has been already described and its main features and geological relations pointed out in a previous paper in these Memoirs.* The relations of the series to the subjacent cretaceous rocks and to the overlying tertiary beds are treated in the last and the following chapters relating to those formations. It will therefore only be necessary in this chapter to describe briefly the area occupied by the volcanic series upon the map now published, and to note such geological characters as especially distinguish it within the area under consideration.

Area covered.

The traps occupy more than three-fourths of the accompanying map. All the higher ground except in the north-western corner is entirely composed of them, as are also very large tracts in the valley of the Nerbudda, and nearly the whole of the Taptee drainage, though in the latter, over a large area, the absolute surface is composed of alluvial soil.

Dips.

Over a considerable portion of this country the traps rest in almost perfect horizontality. This is the case throughout the Malwa scarp, and apparently over a considerable proportion of the valley to the south of it. The same is seen, so

* Vol. VI, Art. 3.

far as the inclination can be made out, in a large portion of Berar, and the dips, if any occur, are very slight indeed in the hills north of the Taptee in Nimar and Baitool. But along the line of the Taptee south-west of Baitool there is a marked southerly dip, though at a low angle, and although the beds are horizontal throughout a large portion of the Gawilgurh hills, there is a dip of about 5° to 10° to the north along their southern scarp accompanied, apparently, by a great fault at their base parallel to the range. Passing to the westward, low dips in various directions are seen amongst the traps of the Satpoora hills. These increase in amount here and there. Some very sharp dips of 10° and even more to the southward are seen in the Nerbudda and just north of the river west of the Hurin Pal; and to this sharp southerly dip, which continues for many miles to the westward, the total disappearance of all infra-trappean rocks south of the Nerbudda appears to be due. The amount of disturbance which the traps have undergone appears to culminate in the Rajpeepla hills. Not only do the beds in this region dip at angles comparatively high (5° to 20°) when their horizontality over immense tracts in the Deccan and Malwa is considered, but dykes are extremely prevalent, and of great size, forming small ridges 100 to 150 feet high parallel and frequently at no great distance from each other. Their general direction is east-north-east to west-south-west.

Disturbance in Rajpeepla hills.

It is very possible that a more close examination of the Rajpeepla hills might exhibit other signs of volcanic agency; unfortunately they were examined at the very commencement of the survey operations before that general familiarity with the traps over large areas had been obtained, which would have enabled those phenomena to be better understood. It is impossible to say without closer search whether any of the inclination which was observed in the lava flows may have been due to original consolidation upon a slope, or whether it is entirely caused by disturbance. That the rocks have been disturbed since their deposition

is clearly proved by the fact that the sedimentary nummulitic beds resting upon them have also been tilted up, but it is also certain that the traps were inclined before the deposition of the nummulitics, and it is not clear to what cause this inclination should be attributed. Judging from the horizontality of the same beds throughout Malwa and the Deccan, it appears probable that they were originally horizontal in the Rajpeepla hills also.

Centre of volcanic action.

The disturbance and the great number of dykes met with in the Rajpeepla hills appear to indicate that this was, during the trappean times, a great centre of volcanic action. In further support of this view is the occurrence north of the Nerbudda, at Matepenai or Kulali hill, of a mass of trap of peculiar structure, which appears to have been the nucleus of a volcano. (See afterwards). To the same cause may be ascribed the great hardening which the sandstones of the Deva valley have in places undergone, and the dykes and irregular intrusive masses of trap which intersect them.

Intrusive masses trachytic.

Matepenai is by no means the only intrusive mass of trap. Many such occur and several of them like Matepenai are of a very different kind of volcanic rock from the usual basaltic lava flows. They are in fact, so far as can be judged by appearance, trachy-dolerites, or in some cases true trachytes. One very considerable mass of a decidedly trachytic rock occurs upon the margin of the nummulitics near Padwani. These more silicious forms of trap are apparently, in all cases, intrusive; all the flows appear to be of dolerite, and the less basic nature of the dykes and volcanic nuclei may be due to their having dissolved more of the quartzose metamorphic rocks, of which they frequently contain semifused fragments.

Vegetation of trap country.

One general character of the trap country which was omitted in the paper already referred to may be mentioned here. It is the very peculiar nature of the vegetation. This has been remarked by many previous writers. It is so marked that

taken in connexion with the flattened summit of the hills and the lines of stratification constantly conspicuously seen upon them, it enables a geologist in Western and Central India to distinguish, almost with certainty, which are trap hills, from a distance even of several miles.

The peculiarity consists in the paucity of large trees, and the abundance of grass, which is frequently 3 to 4 feet in height. This grass dries almost immediately after the end of the monsoon and forms a natural hay, the principal food of the herbivorous animals of the country, both wild and domestic. The paucity of trees appears due to several causes,—the wanton destruction of the forests by wood-cutters, the annual burning of the grass, and its luxurious growth, which must choke the young trees. Locally, on the upland flats, the small depth of soil also is unfavorable to the growth of large trees. Those trees which do occur moreover are, almost without exception, deciduous, and lose their leaves very early in the season, while many do not put forth new leaves till the beginning of the rains. This is especially the case with the Sali *(Boswellia thurifera)*, one of the most abundant. The result is that throughout the cold weather from November till March all the trap country presents an uniform straw coloured surface with but very few spots of green to break the monotony, while in March, April and the greater portion of May after the grass is mostly burnt, the black soil, black rocks, and burnt grass present an aspect of desolation unbroken often by a single green leaf for more than a month after Eastern India is bright with fresh foliage. The only season when the trap country has any beauty is during the rains.

In Section XI of the second part of this Memoir, some remarkable sedimentary beds, forming a large portion of the base of the present series, will be described. These are evidently a large development of the intertrappean formation accumulated under peculiar conditions.

CHAPTER 11.—OLDER TERTIARY BEDS, INCLUDING THE NUMMULITICS.

Area and locality.

Rocks associated with nummulite-bearing beds have but a small extent in the Nerbudda and Taptee country. They occupy two isolated areas of no great extent between those rivers near their mouths, and are also found in one or two very small patches south of the Taptee. In every case they form a fringe to the rocky trap country, and border the alluvium of Guzerat, which conceals them to the westward. North of the Nerbudda they have not been met with in the country mapped. The best sections of them are seen in the Taptee near Gulla, and in the streams which run from the Rajpeepla hill country to the Nerbudda north of the Keem valley.

Mineral character.

The uppermost portion consists of gravels (in which a large proportion of the pebbles are agates derived from the trap), sandy clays and calcareous sandstone, frequently nodular. The gravels are often cemented into a conglomerate. Towards the base, bands of limestone, usually sandy and impure, abounding in nummulites and other fossils, are met with, and, with them, thick beds of a ferruginous clay, assuming, where exposed, the well known brown crust, irregular surface and general appearance, of laterite. Beds of agate conglomerate, apparently of considerable thickness, still occur. These lower rocks are best developed near Turkesur and Gulla and just north of the Keem, about Deenod, Whaliat and Wagulkhore: further north they are not met with in so marked a form, but the lowest beds about Amuljhur, Padwani and Seealee contain large rounded blocks of trap.

Agates and other material derived from the traps.

The enormous amount of trap debris, whether in the shape of fragments of the trap itself, or of the rolled pebbles of agates derived from it, is ample proof of the great denudation which the traps underwent during the deposition of the tertiary beds. Immense beds of agate

pebbles occur high up in the latter, especially in the neighbourhood of Ruttunpoor; from some of these are derived the agates used by the Cambay lapidaries.

Denudation of traps prior to deposition of tertiary beds.

There is, however, evidence that the denudation of the traps had been considerable even before the commencement of the period of deposition of the tertiary beds. It is generally very difficult to ascertain the exact strike of the traps, but about 4 miles south-east of Turkesur, at a village called

Near Ooskur.

Ooskur, a very peculiar bed is found interstratified with the lava flows; it has somewhat the appearance of a hardened shale, but still more that of a fine volcanic ash arranged by water. It is somewhat disturbed, but easily traceable, and it strikes at about west 40° south. The dip is not distinct, but is in places high. The boundary of the nummulitic beds resting upon the trap strikes about south 5° west, and their dip does not exceed 5°; the two lines gradually converge until the tertiary beds completely overlap the band of shaley ash.

There can be no reasonable doubt but that this ash (?) bed is interstratified with the traps. It has in no way the appearance of a dyke or vein, but rather of sedimentary rock. The nummulitics must, therefore, rest on the denuded edges of the traps.

Near Sursho hill.

There is also considerable appearance of unconformity near Sursho hill, east of Ruttunpoor. At the hill itself there is so much disturbance that it is impossible to say what are the relations of the nummulitics to the traps, but east of the hill and south of it,—not, it is true, quite close to the nummulitic boundary, but still not more than a mile or two from it,—the traps have a distinct southward dip, and this is a continuation of a similar dip traceable to the eastward for at least 50 miles. Now, upon these traps, thus dipping south at angles averaging about 10°, rest tertiary beds dipping west and north-north-west at various angles, averaging perhaps

rather more than 10°. The evidence here is less complete than in the first instance, but still it is only a fair inference that the two series are unconformable, and that there was denudation of the traps previous to nummulitic times. Otherwise it is difficult to conceive why the nummulitics do not come in to the south instead of to the west.

Sub-division of tertiary beds in Surat and Broach.

Perhaps the most important and interesting question scientifically is whether the tertiary beds of Surat and Broach comprise one group or more than one, whether the lower portion of the series, with its nummulitic limestone and laterite beds, does not belong to a different epoch from the agate gravels and conglomerate which overlie them, and whether the latter do not represent the miocene beds of Perim. It is tolerably certain that the nummulitic limestone of Turkesur and Gulla is much older than the Perim beds, the former, which contains many species of shells common to the nummulitics of Sind and Cutch, and to the beds of the Paris basin, being unquestionably lower eocene, while the Perim beds which contain ***Mastodon latidens*, *Camelopardalis Sivalensis*, *Sus Hysudricus*, *Dinotherium Indicum*** and ***Brahmatherium*** have been shown by Dr. Falconer* to be of the same age as the Siwalik and Irawadi formations, which are, at the oldest, miocene.

Question as to representation of Perim beds near Surat and Broach.

On this question it is impossible to pronounce an opinion from the evidence obtained. The mineral character of some of the upper beds met with in the Taptee and Keem sections is not dissimilar from that of the Perim conglomerates; both contain rolled fragments of grey sandstone, which was not observed in any beds associated with the nummulitic limestone. But none of the characteristic fossils of either locality was observed in the other; the bones of large Mammalia and the huge masses of fossil wood so abundant at Perim were not met with in the Taptee, Keem, and

* Quar. Jour. Geol. Soc., London, Vol. 1, p. 356.

Ruttunpoor sections,* nor were the shells, shark's teeth, and *balani* of the upper beds of Surat and Broach found at Perim.

A difference in age between upper and lower beds probable.

There is, however, a great change, both in fossils and in mineral character, between the upper and lower beds between Broach and Surat. Until the fossils are more carefully examined than has hitherto been practicable, it is difficult to say if any species occur in both, but the majority, and especially the characteristic fossils, are distinct. The *Nummulites*, *Orbitolites* and other Foraminifera, the *Pectens*, *Ostrea Flemingi*, *Vulsella legumen*, Cones and Corals of the nummulitic limestone, were not met with above, but in their place distinct kinds of oysters, *Pholadidea (Martesia?)* tortoise plates, shark's teeth, foraminifera as *Rotalia* and *Operculina*, apparently all distinct from those below, *Bryozoa*, and, in great abundance valves of *Balanus*, are met with. The differences in mineral character have already been indicated.

Probability of higher group overlapping the lower.

If the two groups are distinct, and the evidence is certainly rather in favor of their being so, it appears probable that the higher overlaps the lower about half way between the Keem and the Nerbudda, as no bed distinctly referable to the lower group is met with north of Wagulkhore.

Imperfection of sections.

It should, however, be remembered that the sections met with were but few and very imperfect, that the rocks only appeared above the surface of the ground in rare instances, and that by far the greater portion of the country was covered and concealed by thick alluvial deposits, even within the small area over which rocks have been marked on the map; and it appears therefore wisest, until the whole question has been worked out in the great nummulitic tracts further west, to abstain from attempting to separate the

* If, however, the occurrence, mentioned ante p. 19, of a jaw of Mastodon having been procured near Broach by Malcolmson be correct, there can be little doubt but that the Perim beds are represented in that country. Still it is not clear what portion of the series they form.

tertiaries of Surat and Broach into groups, and to represent the whole by but one colour on the map. (a)

Thickness of beds.

Of the thickness attained by the tertiaries of Surat and Broach it is difficult to form an estimate for the same reason. No continuous sections exist, and it is difficult to say how large a portion of the apparent thickness is due to repetitions caused by anticlinal and synclinal rolls in the beds or to faults. In the stream which runs past Ruttunpoor, the rocks are seen for above 5 miles. The dip varies much, but the average can scarcely be less than 10°. This would give a thickness of 4,600 feet, which appears excessive, and is, after all, a mere guess. At Turkesur the lower group is about 2 miles wide, and dips at angles of from 5° downwards. Taking the average dip at 5° the thickness would be about 900 feet, but supposing that it is lower, which is more probable, and reckoning it at 3° the total thickness would be 560 feet.

CHAPTER 12.—OSSIFEROUS GRAVELS AND OTHER OLD ALLUVIAL DEPOSITS.

In treating of the general physical geography of the Nerbudda and Taptee valleys, the presence of great plains of alluvium was especially noticed. One such plain, that occupying the Nerbudda valley from Jubbulpore to Hoshungabad, has already been described in these memoirs

(a). It has been already suggested that all the fossils of the Sind nummulitics are not of one age. In the Quarterly Journal of the Geological Society for 1864, Vol. XX, p. 65, several reasons are given by Mr. H. M. Jenkins for believing that some of the Sind beds massed as eocene by most previous observers were of, at least, miocene age. He showed that some rocks of Java believed to be miocene contained a *Vicarya* very near the *V. Verneuilli* of Sind, and that *V. Verneuilli* was associated in Sind with shells occurring in the miocene of Europe. At the same time Dr. Martin Duncan, in a separate note, showed that a large number of corals from Sind, not described by M. M. D'Archiac and Haime, have miocene and even pliocene affinities. The examination of Surat and Broach and of the tertiary beds there occurring was made early in 1863 (January and February), a year before Mr. Jenkins's paper appeared, and in a brief visit to Sind in November 1863, I saw strong reasons for suspecting that a division of the nummulitic formation there should be made. Indeed the occurrence of forms of more recent appearance than nummulitic in the Sind rocks has been for some years known in India.

by my colleague Mr. Theobald (*a*). Only the extreme western edge of this tract is included in the area now examined, which, however, comprises the two great plains of Berar and Khandeish on the basin of the Taptee, and some smaller alluvial flats upon the Nerbudda near Mundlaisur in Nimar, and on the Wurda, east of Oomrawutee. These latter tracts are small and irregular; rock frequently appears in the river beds throughout them, and although the alluvial deposits are of great depth in places, they are not uniformly so over any great extent of country, and it has consequently not been necessary to represent them on the map by a distinct colour, as has been done in the more extensive areas.

Alluvial plains of Taptee and Nerbudda.

The alluvium of the coast of Guzerat differs in no essential character from that of the river valleys, but it will be most convenient to treat of it separately.

The principal characteristics of the deposits forming all these alluvial plains are similar, and have already been described by Mr. Theobald. The upper portion is, in general, brown clay, or rather marl, abounding in carbonate of lime in the form of kunkur, totally devoid of stratification, and passing, at the surface, into a black soil. Beneath this, often with indications of irregular deposition, are gravels and sands, frequently more or less cemented together by carbonate of lime, in a manner which closely resembles the mortar in a rubble wall, and sometimes so hard as to form a solid conglomerate or concrete, which is, in some places, quarried for building. Not unfrequently the clays, towards their base, become sandy and pebbly, and pass into the lower beds. Even high up in the clays, sandy beds are sometimes seen, and in such cases, stratification is distinct, and oblique lamination is at times met with. In the lower and coarser portions, oblique lamination is almost the rule.

Mineral character of alluvium.

(*a*). Vol. II, p. 279.

Thickness.

The thickness of these deposits varies greatly, and it is difficult to estimate it. Sections of upwards of 50 feet in height are occasionally seen on the river banks, more frequently, however, 20 to 30 feet are exposed. In some cases the whole of this thickness consists of gravels and sands. More commonly the greater portion is clay, the coarser beds only being seen towards the base.

Fossils.

Fossil bones in the lower Nerbudda and in the Taptee valleys are by no means abundant, and only a few fragments have been met with here and there. It is probable that closer search will result in additional discoveries, but many hours have been fruitlessly spent in examining the banks of the different rivers, the Taptee especially. Shells are common, and they appear in every case to have been of species (*a*) now met with in the rivers.

Salt in alluvium of Berar.

In one portion of the Berar alluvial plain there is a considerable quantity of common salt in the clay, so much around Dhyunda and other places, north and north-east of Akola, that wells are sunk for the purpose of obtaining brine for manufacture, and much salt is made. This does not appear to be the case elsewhere. The salt-bearing stratum appears to be very low down in the alluvium, the wells which are dug into it being of great depth. It is beneath the gravels, and may, not improbably, be something distinct from the upper fresh water alluvium, and of greater geological age. The presence of common salt in large quantities may also indicate that the clays containing it are of marine origin (*b*).

Present streams do not deposit.

It is evident that these extensive alluvial plains have not been formed by the rivers which traverse them under precisely their present conditions. These streams are now, in fact, wearing away the clays and gravels; they have cut deep

(*a*). Closer comparison than has hitherto been made is, however, desirable. In some cases, where there is no specific distinction, there may be slight differences worthy of note amongst shells so variable as species of *Unio* and *Melania*.

(*b*). I had not myself an opportunity of examining the salt-producing area of the Poorna valley. Mr. Wynne, who surveyed the country, noticed no peculiarity in the alluvial clays.

channels into the alluvial deposits, and the neighbourhood of their banks is often a network of ravines, the result of denudation. The rivers now appear never to overflow their banks; in short, they are clearly denuding and not depositing streams.

Alluvium fluviatile.

There appears, however, good reason for believing that these alluvial deposits are fluviatile. They are certainly in great part, and probably altogether, fresh water, for they contain fresh water shells, and the only question is, whether they are fluviatile or lacustrine. The former appears the more probable (*a*) for the following reasons:

Rolled pebbles and isolated bones.

1*st.*—The occurrence of rolled pebbles everywhere towards the base. Even the bones are isolated, and rolled, single teeth frequently occurring. If the deposits were lacustrine, pebbles could only occur at spots where streams entered the lake, and if bones were found elsewhere, it might be expected that they would occur not isolated, but together, as partial or perfect skeletons, as they must be derived either from carcases floated into the lake, or from animals such as *Hippopotami* or crocodiles which had lived and died in the waters. Complete skeletons might of course also be found in fluviatile deposits; it is solely the presence of isolated bones which is characteristic of beds accumulated by the aid of running water.

Absence of stratification in clay.

2*nd.*—The 'uniform appearance and absence of stratification in the clay' or marl has been quoted as proof of lacustrine origin. But it is a common and almost typical character of river deposits, as may be well seen in those of the great Indian rivers.

Fossil mollusca.

3*rd.*—The character of the molluscan remains. All the fresh-water shells found are of species such as are met with in rivers at the present day. The only difference which can be traced is the absence in the gravels and clays of many species

(*a*). I am compelled to differ from my colleague Mr. Theobald and from some other observers. It is true my observations have been in different districts from those previously examined, but still the beds are so similar that they must, I think, have all had the same origin.

now found. It appears scarcely probable that if, in addition to the lapse of time, so great a change in the physical characters of the country should have taken place as is involved in the conversion of a great series of lakes (*a*) into a simple river valley, no alteration should have occurred in the fresh-water molluscan fauna, except the addition of fresh species. Even the changes which have taken place are to some extent susceptible of explanation. Thus Dr. Falconer, in a most valuable paper upon the ossiferous deposits of various eastern rivers, remarks especially upon the absence, in the Nerbudda deposits, of *Melania spinulosa*, Lam., and *M. variabilis*, Bens., and the rarity of *Planorbis Coromandelianus*, Fabr. But *M. variabilis*, and also *M. lyrata*, Bens., appear to be confined at present in India to the Ganges valley and the neighbourhood of Bengal. *M. lyrata*, it is true, is mentioned by Mr. Theobald as inhabiting the Nerbudda valley, but it is certainly rare, (*b*) and to the west it does not occur. *M. spinulosa* is very locally distributed throughout India. The rarity of the common *Planorbis* is due to another cause. It is not, as a rule, a river shell, it abounds in marshes, and the shells met with in the rivers are chiefly dead shells washed in during floods. Such dead shells, if light, are carried along upon the surface of the water and stranded on the bank, where they decay. In the beds of Indian rivers, by far the greater portion of the shells met with are species of *Paludina, Melania, Unio* and *Corbicula*, precisely the species found most abundantly in the deposits of the Nerbudda and Taptee valleys. They, in consequence of their solidity, and the ease with which they fill with sand, sink to the bottom, and *Lymnea*, which in consequence of its large mouth, is also less suited for floating, often accompanies them.

Both the nature of the deposit and its organic contents therefore appear in favour of its fluviatile origin. It is also evident that if the

(*a*). The upper Nerbudda alluvial plain exceeds 200 miles in length. The Berar plain is about 110 miles long, that of Khandeish 160 miles.

(*b*). I have never seen it: I have met with both *M. tuberculata* and *M. spinulosa* in the Nerbudda.

rivers were again to form deposits, they would be much of the same kind as those found. But in order to become again depositing streams a change in the rate of fall would be necessary, certainly for the deposition of the clay flats. It is probable, therefore, that the rate of fall was less at the time when the alluvial plains of the Nerbudda and Taptee were deposited. Whether the subsequent change has been due to greater elevation of land to the eastward, or of depression to the westward, or simply to the river having cut a deeper channel to the west through the rocky country traversed after leaving the various plains, is more difficult to say.

Alluvium probably deposited when fall of streams was less.

The saltness of part of the Berar plain seems in favour of the presence of the sea at the period of its formation. But the want, so far as is known, of marine remains is opposed to the idea of these plains having been delta accumulations on a sea-coast.

Note on the Godavery Gravels.

In Dr. Falconer's paper above alluded to, mention (*a*) is made of the occurrence of *Elephas Namadicus* in richly fossiliferous fluviatile deposits of southern India. In 1862, I heard from Dr. Falconer of a great deposit of fossil bones in the Godavery valley, which is undoubtedly the same as that alluded to. Dr. Falconer promised to search for a note he had of the precise locality, but I omitted to enquire again about it at the time, and I feared that, with his untimely death, all record of the spot had been lost. Fortunately Sir Bartle Frere was also acquainted with the circumstances of the discovery (no account of which appears ever to have been published) and procured from the original discoverer, General Twemlow, an account of the facts, which he communicated to me. The spot from which the skull examined by Dr. Falconer was obtained was close to Pyton, a town on the Upper Godavery, on one of the roads leading from Ahmednuggur to Jalna. General Twemlow also met with extensive deposits of Mammalian bones in the valley of the Pem (or Pyne) Gunga near the cantonment of Hingolee, and he is of opinion that the ossiferous deposits are largely scattered over the valleys of the Godavery and Pem Gunga. Mr. Fedden has, during the past year, searched a portion of the Pem Gunga valley near Hingolee, and has found fossil bones, chiefly bovine, in several places, though not in that abundance which the earlier accounts had led to be anticipated. The numbers mentioned by General Twemlow must have been an accidental accumulation. Mr. Fedden after much search and enquiry succeeded in discovering a spot near Hingolee where bones were said to have formerly occurred in large numbers, but he only met with a few fragments. It is to be hoped that observers residing in the country will carry on the search.

(*a*). Quart. Jour., Geol. Soc., London, Vol. XXI, p. 381.

Alluvium of Guzerat. As already mentioned, this is similar in its main features to the alluvium forming the plains of the river valleys. Like them it consists of brown clay, containing kunkur above, and of conglomerates, gravels and sands below. The streams cut deep ravines through it, and it forms cliffs of some height along their banks. Its surface is frequently, as near Broach, perfectly horizontal over large surfaces, at other times slightly undulating in consequence of inundation.

Similar to alluvium of river plains.

It is by no means clear by what process this alluvial deposit has been formed. It is very similar to that seen along a large portion of the Indian coast, and which is usually supposed to have been recovered from the sea by a slow process of upheaval. But how this has taken place is not so evident. Along the sea itself, where raised coast lines are constantly met with, they usually consist of blown sand-hills, and similar hills fringe the present shore; so fine a sediment as that which has formed the fertile plain of Guzerat is deposited in comparatively deep water at a distance from the breakers. During slow emergence from the sea the upper portion of the clay would be mixed with and covered by sand. But the reverse is the case, the sand is covered by clay, and it is therefore more probable that the latter is a river deposit. In favor of this is the fact that wherever shells have been seen associated with it they are of fluviatile species, but they have only been noticed at a considerable distance up the rivers and near the hill country.

Origin obscure.

It is possible, and even probable, that the clays of Guzerat may have, to a considerable extent, accumulated in 'backwaters,' that is, in coast lagoons. Still it does not seem likely that these could have covered the whole surface, and the uniformity of the deposit is remarkable. The carbonate of lime now existing as kunkur may have been originally derived from shells as has frequently been suggested before. One peculiar circumstance in connection with these deposits was noted on the Nerbudda

below Broach. The alluvium which formed cliffs along the river banks was not only much consolidated (apparently through cementation by carbonate of lime), but the beds in places were seen curved as if disturbed. The curves, however, so far as was seen, were always synclinal, and may perhaps have been formed during the filling up of channels in the pre-existing alluvium by newer deposits. All of these alluvial deposits, however, require a more careful and thorough search and examination for indications of their origin than it is practicable to give to them, while so many more important questions await solution. Enormous tracts are covered by them, they are the richest and most thickly populated districts of the country, and they are eminently deserving of study, if only for agricultural purposes, for upon their distribution depends, to a great extent, the kind of grain grown and consequently of food consumed by the people of the country. But their geological history is still very obscure.

Appearance of disturbance.

Alluvial deposits of India still imperfectly known.

CHAPTER 13.—NEWER FORMS OF ALLUVIUM AND SURFACE SOIL.

Along the present course of the rivers, as might be expected, small flats, (straths) but little above the level of the river, and liable to flooding, occur every here and there; they are broader and more conspicuous in the lower parts of the valleys where the fall is less. The soil upon them is usually very fertile; it consists of a more sandy clay than the older alluvium, and it has not, in general, a covering of black soil. It is, however, palpably formed from the older alluvium and other surface soils, washed by rain into the rivers, and redeposited during floods. Thus, though rarely formed entirely of regur or black soil it frequently contains a large proportion of it mixed with other clays and sand.

Small flats along present course of rivers.

There is nothing in the occurrence of this newer form of alluvium which needs description. It is only necessary to note its occasional

occurrence, and its distinctness from the more ancient deposit. Frequently intermediate forms occur, which are by no means easy to distinguish.

Blown Sand.—This is met with along the coast between the mouths of the Nerbudda and Taptee. It presents no peculiarities.

Cotton Soil or Regur.

Black Soil or Regur.—This is the common soil of the whole of the Deccan, Malwa, the Taptee and Nerbudda valleys and Guzerat. Its peculiar characters have been so often described that any thing that can possibly be said about it will be a mere recapitulation of what has been said before. It varies greatly in colour, in consistence, and in fertility, but preserves the constant characters of being highly argillaceous, somewhat calcareous, of becoming highly adhesive when wetted, (a fact of which any one who has had to traverse a black-soil country after a shower of rain becomes fully aware,) and of expanding and contracting to an unusual extent under the respective influences of moisture and dryness. Hence the great cracks by which it is fissured in the hot weather. Like all argillaceous soils, it retains water, and hence requires less irrigation than more sandy ground.

Passage into alluvial clay and trap.

In the alluvial flats it passes downwards into the brown calcareous clay; on the uplands it passes similarly down into decomposed trap. It is never of great depth, never, except where rearranged by rivers in their recent deposits, met with at any distance below the surface. It is not surprising that a host of observers, from Voysey to Carter, should have contended, and should still contend that it is only disintegrated trap; over thousands of square miles it is unquestionably derived from decomposed basaltic rocks; every stage of transition from hard basalt to true regur can be seen in thousands of sections. More than this, over enormous areas the boundary of the trap rock below is the boundary of the regur above (*a*). Nothing

(*a*). This is admirably seen throughout the Nagpúr and Chanda country. Everywhere on the trap regur recurs; a few miles to the eastward, upon the metamorphic rocks, it is never seen, except on the surface of alluvial soil brought from the trap country by rivers, such as the Godavery.

seems clearer as a case of induction than the inference that the black soil is solely derived from decomposed trap.

Derived from waste of metamorphic rocks in Southern India.

And yet it is no more necessarily decomposed trap than the red soil itself. As Newbold shewed, long ago, there are hundreds of square miles in Southern India, in the vallies of the Pennar, Palar, Kávery, and other rivers still further to the south, in which the surface is composed of precisely similar "regur" to that of the Deccan. True, it is, as a rule, far less fertile, but it is notorious that the black soil of Western India varies *ad infinitum* in its fertility. There is not a solitary reason for supposing that the basaltic Deccan trap ever existed in the valleys of the rivers above named, nor can there be any reasonable doubt that the alluvial flats contained in these vallies are mainly formed from the detritus of metamorphic rocks.

Hislop's theory.

Hislop appears to have pointed out the most probable origin of the black soil. Its characteristic colour, he considers, is due to the surface impregnation of various argillaceous soils by organic matter (*a*). Every thing observed in Western India tends to confirm this view, and it appears probable that any argillaceous soil may become regur under favorable conditions.

Regur merely a superficial variety.

That it is a mere surface condition may be seen frequently on the alluvial plains so often alluded to. In these, where the wash of rain has swept away the surface on the sides of hollows, the clay is brown; on the flats above it is black: the black soil, however, washed from the sides of the hollows, has frequently accumulated towards the lower portion of them. It is also a common thing to see in the trap country a reddish soil upon the slopes of the hills, while the black soil occupies the bottom of the

(*a*). The resemblance between the regur of India and Tchornozem of Russia was first pointed out by Newbold. It is especially referred to by Hislop.

valleys (*a*). This appears due to the more argillaceous portions of the disintegrated basalts being washed away from the slopes and deposited in the valley, forming a soil much more retentive of moisture and consequently more marshy and more impregnated with organic matter (*b*). Of course agricultural processes tend to change the surface and to obscure the history of these deposits.

Cause of boundary of cotton soil and of traps being identical.

The abrupt termination of the regur at the edge of the traps is simply due to a change from an argillaceous soil to a sandy one. The traps appear almost always to decompose into a highly aluminous substance; the metamorphic rocks, on the other hand, yield sand to a large extent, while the finer kaolin produced by the disintegration of their felspar is, to a great extent, washed away by rain, leaving an excess of quartz sand in the soil. Where this kaolin is redeposited as clay, there is often a surface of regur as in Southern India.

These views will probably reconcile all the difficulties concerning the distribution of regur.

(*a*). This has been pointed out by Mr. Dalzell in a communication published in one of the Bombay newspapers.

(*b*). An instance outside of the area now described may be here mentioned to shew the effect of retention of moisture and marshy condition in blackening the soil. About 3 miles south of Poona, near the Parsee Towers of Silence, are several rises, upon which two terraces, formed of different beds of trap, are conspicuous. The uppermost of these terraces evidently consists of a less pervious stratum than the lower one—the vegetation upon it is rank, abounding in a species of *Carex* and other marsh loving plants. Upon this terrace the soil is black; upon the other, which is much drier, it is a reddish brown.

PART II.

DETAILED DESCRIPTIONS.

SECTION 1.—NORTH OF THE NERBUDDA FROM BHOPAL AND HOSHUNGABAD TO SUTWAS AND CHANDGURH.

This portion of the country embraces, besides the valley of the Nerbudda, a small tract of the Bhopal table-land, which is drained by the head waters of the Betwa. Here the Vindhyan rocks appear, for the last time, in the neighbourhood of the Nerbudda, in any portion of the table-land, their more western exposures in this direction are confined to the low ground in the immediate neighbourhood of the river.

Distribution of formations.

The table-land rises abruptly from the flat ground of the valley, part of the scarp to the east being formed of Vindhyans, while to the west it consists entirely of trap. The surface in the valley is variously constituted, trap, Vindhyans, Bijawurs and metamorphic rocks all occurring, while the greater portion of them are concealed beneath alluvium.

Road from Hoshungabad to Bhopal.

The road from Hoshungabad to Bhopal passes for the most part over Vindhyan rocks. On leaving the river it ascends almost immediately, the hills at Hoshungabad coming down close to the north bank of the Nerbudda. The ascent to the table-land is gradual over well bedded pink or purplish quartzite-sandstone, dipping at a low angle to south-west by south. About the summit level a patch of overlying trap is traversed, but it is of no great extent. About 12 miles south of Bhopal, a cotton soil plain is entered, which continues for 5 or 6 miles, the road then crosses trap, and Vindhyans come in again about 2 miles from the city of Bhopal, which stands upon them.

Hills of trap and Vindhyans, south-west of Bhopal.

South-west of Bhopal the boundaries of the Vindhyans and the trap are very irregular, the trap having evidently been poured out upon a very uneven surface of the sandstone, a surface probably produced by the unequal action of subaerial denudation. Some hills are of one rock, some of the other, but the distinction between the two may be seen at a glance, in consequence of the difference in form and colour, between the rocks of the two groups, and in the vegetation growing upon them. The Vindhyan hills are rocky, generally escarped on one side, and sloping away at an angle of 5° to 7° on the other, they are purplish in colour, bare of grass and covered with thin jungle. The trap hills are flat-topped, blackish in colour and covered with scrub jungle and long grass, shewing the great amount and richness of the soil derived from the basaltic rocks. The Vindhyans stand out, as a rule, in higher hills than the trap, owing to the manner in which they resist disintegration.

Western boundary of Vindhyans, south of Bhopal.

Further south the boundaries between the two rocks are well marked and regular, the Vindhyan area, which stretches away to the east, terminating abruptly about 12 miles west of the road from Hoshungabad to Bhopal. South of Shumsgurh, the Vindhyans rise in a bold cliff-like scarp from the comparatively flat plain of the traps. So steady and regular is this scarp that it has very much the appearance of being along a line of fault, for the older rocks are found along it higher in position and dipping away from the newer. But it appears more probable that the escarpment existed previously to the formation of the trap, and that the lava flows, now consolidated into that rock, filled up a great hollow worn out in the Vindhyans. In favour of this view are several facts. 1.—The changes which take place in the direction of the scarp, such changes being unusual in faults, although they do occasionally occur. 2.—The absence of any disturbance of the beds near the junction. Such would probably

Vindhyan escarpment probably pre-trappean.

be conspicuous if the boundary were a line of fault. 3.—The continuation of the line of division north to the neighbourhood of Bhopal, where the junction, as already mentioned, is quite irregular, the Vindhyans rising as isolated hills from the plain of the traps. It cannot be supposed that each of these little hills is surrounded by a series of faults, but if they are pre-existing elevations around which the traps have accumulated, there seems no reason why the larger scarp should not have been so also. The present elevation of all the Vindhyan hills above those of the trap is of course due to their far greater power of resisting atmospheric action, and their consequently slow disintegration.

Petrological character of Vindhyans near Bhopal.

The beds of the Vindhyans immediately south of Bhopal are composed of the fine purplish quartzite-sandstone, so common in this part of the country, rippled in places, occasionally false-bedded, and, near Shumsgurh, marked with distinct bands of colour. Occasional beds of conglomerate occur, containing pebbles of granitic or gneissic rocks and of quartzite, the latter often purplish and precisely resembling the matrix in which they are contained. Small pieces of shale and fragments of red jasper also occur, but they are rare.

Dips.

The dips are always low. Some of the beds are very massive, and form well marked ridges. One ridge in especial occurs just west of the Bhopal and Hoshungabad road, south of the village of Akulpoor and Dohattia. The rocks dip about 5° to the north, and weather on the top of the ridge into immense crags, which are conspicuous from a great distance. The northern or longer slope of the hill, as is generally the case with the Vindhyan sandstone ridges, corresponds with the bedding of the rocks. This ridge, after running east and west for 5 or 6 miles, turns sharply to the north-west close to the small village of Jowra, the twist corresponding with a change in the strike of the rocks, which thence dip north-east. In the course of some miles, their dip gradually changes

to the east, and the strike of the range to the north. Other parallel ridges occur, shewing the same phenomena, but they are less conspicuous.

Boundary south of Shumsgurh.

To return to the boundary of the Vindhyans and traps south of Shumsgurh. The escarpment of the former continues south to the edges of the table-land, and the same line of division is continued, in the same direction, down into the Nerbudda valley, about 1,000 feet below the plateau, so that the original Vindhyan scarp, before the traps were formed, must have been 1,000 to 1,200 feet in height at least, and the traps must have filled up this depth before they overflowed the Vindhyans of the Bhopal and Saugor plateau.

Vindhyans near Gunnoorgurh.

With their usual power of resisting denudation, the Vindhyans stretch out into the Nerbudda valley far south of the trap escarpment and even appear on the river itself at Murdanpoor. At the point where they commence to jut out into the plain, they rise into the hill fort of Gunnoorgurh.

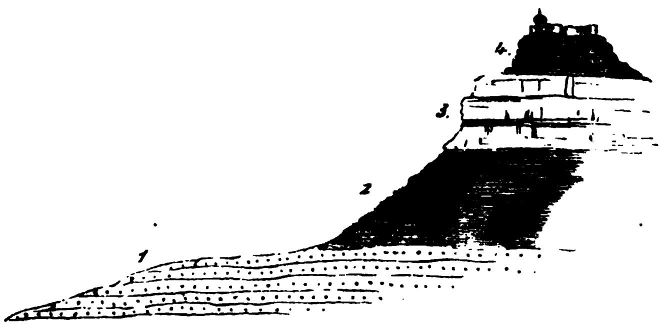
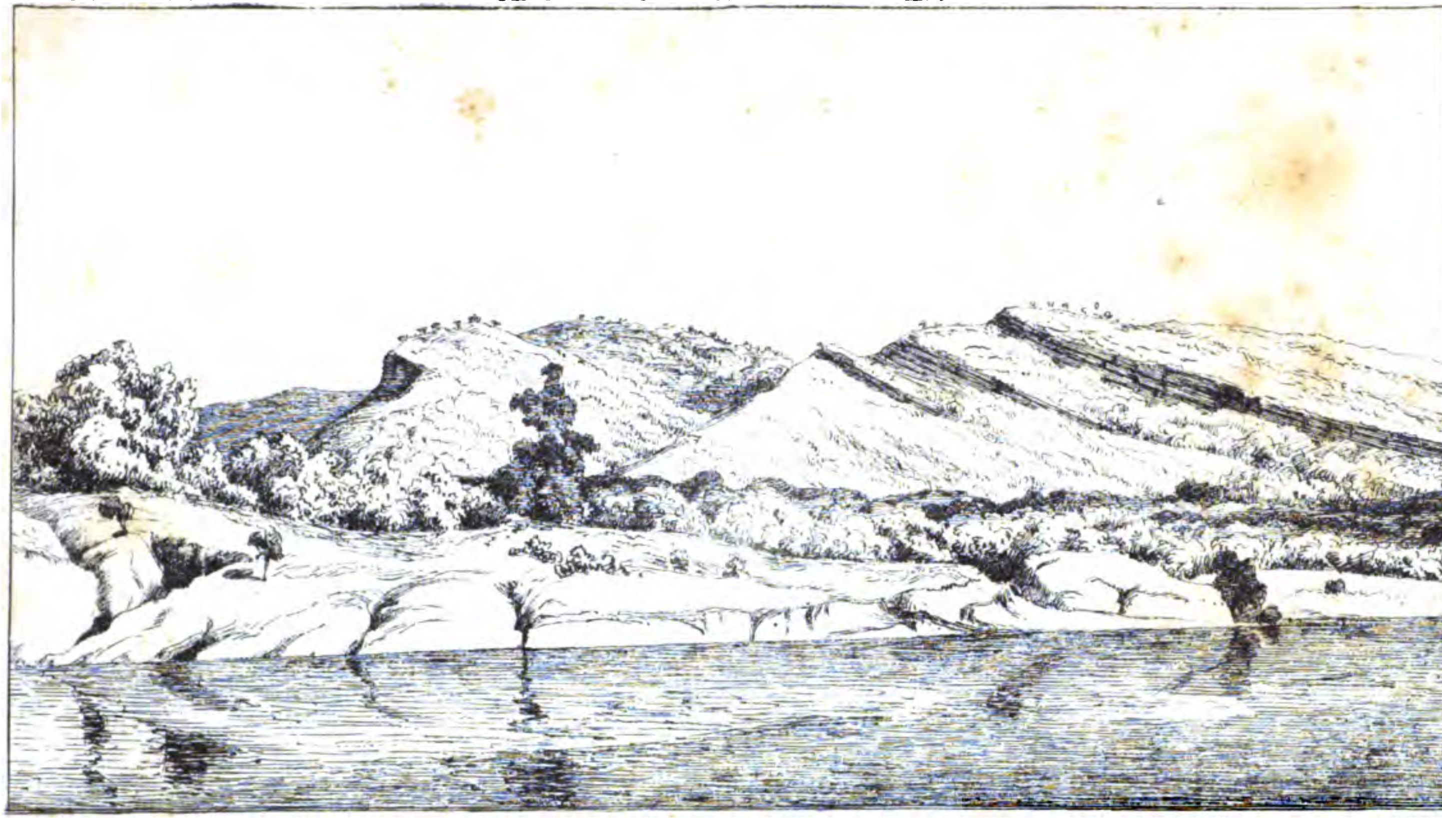


Fig. 2, Sketch Section of the Hill of Gunnoorgurh.

1, Strong red quartzite-sandstone: 2, greenish and grey shales, thinly laminated: 3, red shaly beds, soft red shales in the lower part: 4, grey shaly flags.



Photozinc. Surveyor General's Office, December 1863.

Hills near Murdanpoor seen from Nerbudda.

Ascending from the low ground of the valley towards the fort, the usual purplish quartzite-sandstones are traversed, but the hill itself is formed of fine flags and flaggy shales, slightly calcareous in some places. The lower portions of them frequently exhibit the fine rippling so characteristic of the Vindhyans, higher up the beds are smooth and level, their colour varying from light greenish-grey to deep red, some are concretionary and sandy, and all have so perfectly unaltered an appearance, that a geologist is disappointed when he finds them unfossiliferous. *(a)*

Trap south of Gunnoorgurh.

Immediately south of Gunnoorgurh, between it and another hill of Vindhyans, is a valley, the bottom of which is composed of trap, whilst about 6 miles west-north-west of Gunnoorgurh, a small hill of Vindhyans occurs surrounded by trap. These two circumstances are additional proofs of the non-faulted nature of the Vindhyan and trap boundary, and shew that the views above expressed of the Vindhyan escarpment being due to denudation in pre-trappean times, and not to subsequent faulting, are correct.

Hills north-east of Murdanpoor.

The low ridges which stretch out into the plain of the Nerbudda north-east of Murdanpoor, consist of fine purple sandstone and conglomerate, enclosing semi angular pieces of purple quartzite, decomposed fragments of metamorphic rocks, and some small flakes of mica. The beds are much weathered, and perhaps calcareous. All the Vindhyan hills in this part of the Nerbudda valley have a very peculiar appearance, illustrated in the accompanying sketch by Mr. Wynne (Plate VI).

Nerbudda east of Murdanpoor.

As has been stated, a small section of the Vindhyans is seen in the Nerbudda, east of Murdanpoor. A low hill just south of the river at this spot, is also composed of these rocks.

(a) As before mentioned, these beds, the description of which is copied from Mr. Wynne's note book, have been ascertained by Mr. Mallet to belong to the Bundair division of the Vindhyan series.

West of the Gunnoorgurh spur, the plain north of the river is mainly covered over by alluvium. To the north the scarp of the table-land is entirely composed of trap. The country is geologically very uninteresting as far as the neighbourhood of Hurrungaon. South of this place metamorphic rocks emerge here and there from beneath the alluvium. They are granitoid in places. Patches of overlying trap rest upon them, and a considerable thickness of alluvium conceals the greater portion of the rocks.

Country west of Gunnoorgurh.

Hurrungaon.

West of Hurrungaon are two hills, conspicuous from a distance, composed of very massive quartzite, of peculiar appearance, which may possibly be metamorphic, or, perhaps, Bijawur. The connexions, however, were not made out. The accompanying sketch (Fig. 1, Pl. VII) illustrates the appearance of one of these hills formed of white granular quartzose rock, that furthest to the west, near the village of Sagonia. The other sketch (Fig. 2) illustrates the contrast afforded by the outline of the trap hills.

Hills of quartzite west of Hurrungaon.

On the Bhowra ghat by which the scarp of the Malwa table-land is ascended, north of Hurrungaon, there is far less appearance of bedding than is usual in the traps of the Malwa plateau, especially further to the west. The basalts are very columnar, a character which is common in the lowest beds of the traps in this part of the Nerbudda valley.

Bhowra ghat.

Metamorphic rocks appear in force about Kunnod. Much granitic and syenitic rock is associated with them. Crystalline limestone is occasionally seen, as near Aujnas. Peculiar quartzites are met with at Nimawur, on the Nerbudda and in other places.(a)

Metamorphics near Kunnod and Aujnas.

(a). This quartzite has been recognised by Mr. Mallet as belonging to the Bijawurs. The remainder of this tract was only very cursorily surveyed by Mr. Wynne, whose instructions were limited to laying in the boundaries of trap, Vindhyans and Metamorphics. It has since been examined more closely by Mr. Mallet, whose observations will be published separately.

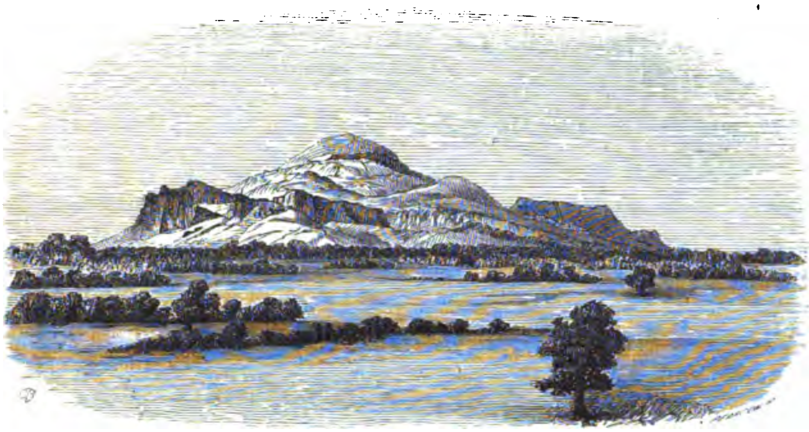


Fig. 1. *Hill formed of granular quartz rock, near* SAGONIA.

Fig. 2. *Outline of trap hill, near* HURRUNGAON.

Below the coarse conglomerate is brown sandstone, slightly conglomeritic. This rests on felspathic sandstone, succeeded by flaggy beds and carbonaceous shale; the latter clearly belonging to the Damuda series. Despite the unconformity between the two series shewn by the Damuda detritus contained in the Mahadeva conglomerate, it was impossible precisely to determine the line of separation. It is clear, however, that the Mahadevas do not, at this spot, exceed 200 feet in thickness, and probably half that amount is nearer the truth.

Up the Morun river the Damudas soon turn over to the south, and disappear again below the traps. The Mahadevas appear to be wanting. They are, however, much thicker in the hills east of the Morun than in the river. No good sections are seen.

Hills near Mukrai.

The hills further west, about Mukrai, are composed of bedded trap, either dipping at low angles to the south, or horizontal. Some inter-trappeans occur in the upper part of the Agni stream, west-south-west of Kaleebheet.

Extension of alluvial plain in direction of Charwa.

South of Hurda, towards Charwa, there is a great bay of the alluvium stretching further to the west, than is the case near the river. This larger quantity of surface deposit away from the river appears to indicate a former distribution of the rivers throughout this country different from that at present prevailing. It may have some connexion with the great break near Aseergurh in the hills which separate the vallies of the Taptee and Nerbudda.

Neighbourhood of Nerbudda west of Hurda.

The trap demands but little notice, and the neighbourhood of the Nerbudda west of Hurda received so very hurried an examination, that but little of importance can be stated concerning it. (a) The rocks consist principally of metamorphics and Bijawurs, overlying trap occurring here and there.

(a). It has since, like the neighbouring country north of the river, been examined by Mr. Mallet, who will probably describe it in greater detail.

On the Nerbudda, a range of hills formed of quartzite rises from the alluvial plain about 2 miles west of Hindia. This range stretches along the river for some distance to the westward. Similar quartzite occurs, as already mentioned, at Nimawur, north of the river, opposite Hindia.(a)

Quartzite hills near Hindia.

About Hurda syenitic and granitic rocks occur. Much alluvial cotton soil covers the surface, but it is often very thin. Thus, in one place, a few miles west of the town, on the road to Kundwa, although no rock whatever was visible on the surface, blocks of granite for the railway works were being quarried from a depth of only 6 or 8 feet.

Metamorphics near Hurda.

In the Machuk river trap is found about Dunwara. In the upper part of this stream no rock is met with as a rule, although trap is exposed near Mohunpoor and Gahal. About half a mile below Dunwara coarsely crystallized pegmatite, (or rather protogene,) containing a chlorite-like mineral, is met with, and forms the bed of the stream for a considerable distance. At Devapoor there is metamorphic limestone. The rocks are extensively metamorphosed and no foliation can be recognised.

Section in Machuk river.

In the country between the Machuk and the Tawa, large outliers of traps overlie the metamorphic rocks. The same is the case north of the Machuk, but to a smaller extent. No attempt has been made to ascertain precisely the boundaries of these numerous little patches : the larger areas have been roughly surveyed, so as to indicate the general mode of occurrence. Most of the patches are oval or oblong, their larger axis corresponding with the general strike of the metamorphic rocks, or about east 20°-30°-north, and it is evident that they are due to the traps having overflowed the irregular surface of the underlying formations, in which, as at the present day, ridges of the harder beds, chiefly quartzite or compact granitoid gneiss,

Outliers of trap between the Machuk and the Tawa.

(a). This quartzite has been shewn by Mr. Mallet to belong to the Bijawurs.

Below the coarse conglomerate is brown sandstone, slightly conglomeritic. This rests on felspathic sandstone, succeeded by flaggy beds and carbonaceous shale; the latter clearly belonging to the Damuda series. Despite the unconformity between the two series shewn by the Damuda detritus contained in the Mahadeva conglomerate, it was impossible precisely to determine the line of separation. It is clear, however, that the Mahadevas do not, at this spot, exceed 200 feet in thickness, and probably half that amount is nearer the truth.

Up the Morun river the Damudas soon turn over to the south, and disappear again below the traps. The Mahadevas appear to be wanting. They are, however, much thicker in the hills east of the Morun than in the river. No good sections are seen.

Hills near Mukrai.

The hills further west, about Mukrai, are composed of bedded trap, either dipping at low angles to the south, or horizontal. Some inter-trappeans occur in the upper part of the Agni stream, west-south-west of Kaleebheet.

Extension of alluvial plain in direction of Charwa.

South of Hurda, towards Charwa, there is a great bay of the alluvium stretching further to the west, than is the case near the river. This larger quantity of surface deposit away from the river appears to indicate a former distribution of the rivers throughout this country different from that at present prevailing. It may have some connexion with the great break near Aseergurh in the hills which separate the vallies of the Taptee and Nerbudda.

Neighbourhood of Nerbudda west of Hurda.

The trap demands but little notice, and the neighbourhood of the Nerbudda west of Hurda received so very hurried an examination, that but little of importance can be stated concerning it. (*a*) The rocks consist principally of metamorphics and Bijawurs, overlying trap occurring here and there.

(*a*). It has since, like the neighbouring country north of the river, been examined by Mr. Mallet, who will probably describe it in greater detail.

On the Nerbudda, a range of hills formed of quartzite rises from the alluvial plain about 2 miles west of Hindia. This range stretches along the river for some distance to the westward. Similar quartzite occurs, as already mentioned, at Nimawur, north of the river, opposite Hindia.(a)

Quartzite hills near Hindia.

About Hurda syenitic and granitic rocks occur. Much alluvial cotton soil covers the surface, but it is often very thin. Thus, in one place, a few miles west of the town, on the road to Kundwa, although no rock whatever was visible on the surface, blocks of granite for the railway works were being quarried from a depth of only 6 or 8 feet.

Metamorphics near Hurda.

In the Machuk river trap is found about Dunwara. In the upper part of this stream no rock is met with as a rule, although trap is exposed near Mohunpoor and Gahal. About half a mile below Dunwara coarsely crystallized pegmatite, (or rather protogene,) containing a chlorite-like mineral, is met with, and forms the bed of the stream for a considerable distance. At Devápoor there is metamorphic limestone. The rocks are extensively metamorphosed and no foliation can be recognised.

Section in Machuk river.

In the country between the Machuk and the Tawa, large outliers of traps overlie the metamorphic rocks. The same is the case north of the Machuk, but to a smaller extent. No attempt has been made to ascertain precisely the boundaries of these numerous little patches : the larger areas have been roughly surveyed, so as to indicate the general mode of occurrence. Most of the patches are oval or oblong, their larger axis corresponding with the general strike of the metamorphic rocks, or about east 20°-30°-north, and it is evident that they are due to the traps having overflowed the irregular surface of the underlying formations, in which, as at the present day, ridges of the harder beds, chiefly quartzite or compact granitoid gneiss,

Outliers of trap between the Machuk and the Tawa.

(a). This quartzite has been shewn by Mr. Mallet to belong to the Bijawurs.

stood up above the general level of country. Where denudation has so far removed the traps that the old surface is once more visible, the hard ridges again protrude, while some trap yet remains in the hollows between them.

Trap dykes.

Trap dykes occasionally occur in the metamorphics. They were especially observed in the jungles north-east of Poonghat. They appeared at that place to have two principal directions, south-east and east-20°-north, the latter coinciding with the lamination of the metamorphics.

Tawa section.

A very interesting section occurs in the Tawa (*a*) river near its junction with the Nerbudda. At the mouth of the Tawa, the Bijawur limestone is seen presenting a peculiar concentric structure; the alternating bands of siliceous and calcareous minerals, instead of being plane, are concentric around nuclei of quartz. Many of these concentric masses are of great size.

A little further south, there is an immense mass of hard quartzose breccia similar to that seen north of the river, north-west of Chandgurh, composed of purplish jasper-like rock with enclosed angular fragments of quartzite. Upon this rest Vindhyan shales, sandy as usual, and passing upwards into the typical quartzite-sandstone, which forms hills west of the stream.

It is difficult to say what is the position of the breccia. It was at first supposed to be Bijawur, but the occurrence of similar breccia apparently interstratified in the Vindhyans on the Nerbudda close by, renders it possible that it may belong to that series.(*b*) The shaley beds appear to be unconformable upon the breccia, and the breccia upon the Bijawur limestone, but neither unconformity is very clearly made out, and apparent unconformities of breccia or quartzite beds resting upon Bijawurs must be regarded with suspicion on account of the predominance of cleavage foliation in some of the beds of that series and its absence in the hornstones and quartzites.

(*a*). This is the smaller Tawa called the Chota Tawa or Sooktawa rivers.

(*b*). This was pointed out by Mr. Mallet.

Higher up in the Tawa, trap comes in, and further on still, there is a patch of metamorphic rocks. It is of no great extent. The rock is granitoid.

SECTION 3.—NERBUDDA VALLEY NORTH OF THE RIVER, FROM CHANDGURH AND SUTWAS TO BURWAI AND THE SIMROL GHAT, INCLUDING THE DHAR FOREST.

Characters of Dhar forest.

Passing westwards from the open alluvial tract of the Nerbudda which extends to Hurda and Nimawur a large expanse of wild, almost uninhabited country, is traversed by the river. This tract is still bordered on the north by the scarp of the Malwa plateau, here entirely composed of trap, but instead of the lower country near the river being level, as near Hoshungabad, it is extremely hilly and rocky. A large portion of this region of jungle belongs to the principality of Dhar, and is known as the Dhar forest.

Rocks occurring.

The river itself traverses Vindhyan sandstone during by far the greater part of its course between Chandgurh and Burwai; farther north the peculiar limestones and breccias of the Bijawurs prevail, and in some spots metamorphics are seen, but they are much less frequently met with than further east, while to the west outliers of the cretaceous beds of Bagh occur.

Rocks in Nerbudda below Balkaisir.

In the Nerbudda near Balkaisir, metamorphic rocks are seen, and they extend to the west nearly to Nowahatta, where a great band of hornstone-breccia crosses the stream, striking east-20°-north. Below this, the bed of the river and its immediate neighbourhood are principally occupied by overlying trap or by masses of conglomerate, which appear to be of comparatively recent date.

It is not clear whether the band of breccia marks a fault, or whether it belongs to the Bijawurs. The latter contain similar beds in this neighbourhood.

West of Chandgurh.

From Chandgurh for 2 or 3 miles to the west, the surface rock, north of the Nerbudda, appears to be trap, covered by immense masses of the same peculiar conglomerate as that seen in the river. This forms a low range of hillocks south of Chandgurh. It consists of pebbles and rounded blocks, often a foot in diameter, and, for the most part, of Vindhyan quartzite-sandstone; these pebbles are contained in a deep red sandy matrix. This is usually but slightly coherent, though sometimes hard.

Conglomerate.

If this conglomerate be a deposit made by the Nerbudda, the course of that river at the time the bed was formed must have been very different from what it is now, for while the mass of the conglomerate consists of Vindhyan pebbles, those of metamorphic rocks being rare, the Vindhyan pebbles occurring in the present river bed are few in number, when compared to those of the metamorphics, and small in size, having been washed down from near Hoshungabad and Murdanpoor, below which no rocks of the series occur in the river's bed till below Chandgurh. The materials for the conglomerate must therefore, in all probability, have been derived from the west, that is, from the direction towards which the river now flows.

Vindhyans and Bijawurs near Chandgurh.

About 2 or 3 miles west of Chandgurh, the Vindhyans come in again with a scarp which stretches to the north as far as near Sutwas. It is noteworthy that this boundary is very nearly parallel to that which marked the limit of the same rocks to the west, between Bhopal and Murdanpoor. Along the edge of this scarp and to the east of it, there are some few exposures of Bijawur beds, interesting, because of the prevalence of a peculiar hornstone-breccia in them, and of the evidence afforded of the complete unconformity with which the Vindhyans rest upon them. The beds are much obscured by the conglomerate of rolled Vindhyan pebbles already alluded to.

Bijawurs near Bhirakhul.

Half a mile west of the village of Bhirakhul there is a better exposure of the Bijawurs than usual. The silicious limestone is first seen with a variable dip. At one spot it dips south-west at 35°, at another, a little further on, the dip is south-35°-east at 45°. Associated with it, in masses which appear to have a somewhat similar strike, is a purplish quartzite, which frequently encloses angular fragments of the limestone of various sizes; presenting much the appearance that an igneous rock might produce if injected amongst crushed strata. Of course the quartzite can scarcely be igneous in its origin. Even if it could be fused, its co-existence in the fluid state with carbonate of lime, without chemical change, would be incredible. It is a case, and a very remarkable one, of brecciation, of which so many instances occur amongst these beds.

The limestone stretches for a long distance, and rests upon an opaque quartzite resembling vein-quartz: then follow thin grey grits all with the same dip of cleavage-lamination as the limestone. The next bed is a broad band of breccia, a magnificent rock for ornamental purposes, consisting of angular fragments of milk-white quartz in a matrix of red jaspery hornstone (*a*).

The fragments of quartzite are at times irregularly intermixed, at others in perfect order, stratum by stratum, but between every little band, and in numerous cracks separating the angular fragments of which the strata are formed, occurs the red hornstone as if injected. The appearance is remarkable, and not easy of explanation, unless it be supposed that the quartzite was crushed and the hornstone then deposited between the fragments. But the distance of the fragments of quartzite from each other is too great for this hypothesis to be satisfactory.

(*a*). This appears to resemble the Tirhowan breccia described by Mr. H. B. Medlicott, in M. G. S. I. Vol. II.

Vindhyans succeed to this bed. There is no reason for supposing the contact other than natural, and in that case there is as usual utter unconformity between the two series, the lamination of the Bijawurs dipping apparently at a high angle to the south-east while the overlying Vindhyans are inclined at a very low angle to the west or west-south-west.

Junction of Vindhyans and Bijawurs.

The Vindhyans are whitish massive quartzites with irregular streaks and patches of purple, the latter apparently caused by the presence of iron. With these are associated thinly bedded quartzite sandstones, containing small rounded fragments of micaceous shale, which resemble splashes in the rock; these may originally have been rolled fragments of clay or silt. Along the scarp to the north, the most conspicuous beds, as usual, are the massive purplish quartzite-sandstones.

Character of Vindhyans north-west of Chandgurh.

A fine section of the Vindhyans is exhibited in the Nerbudda between Chandgurh and Burwai. A portion of this has already been described in Mr. J. G. Medlicott's report,† but as the conclusions now arrived at are different to a very slight, though not unimportant extent, it will be well to redescribe the whole section.

Section of Vindhyans in Nerbudda.

On the north bank of the Nerbudda, opposite to the spot where the Tawa joins, and close to the village of Bauria, a large block of Bijawur limestone stands up in the bed of the river. Thence to the west trap, capped by the massive subrecent conglomerate already mentioned, covers the section for some little distance. Passing down the river, the traps are seen to abut against a mass of bedded brecciated and conglomeritic quartzite, striking east-10°-north, vertical. Along its southern side are a foot or two of softish sandy beds. It is succeeded on its northern side by peculiar red nodular rippled quartzose shales with interstratified flaggy sandstone-quartzite. A little farther west, down the river, the same beds are much crushed,

Pullasee section.

but just beyond they again continue steadily, their strike becoming west-25°-south, dip about 80° to the northward. About 100 yards farther massive purplish sandstone-quartzites (a) rest upon these beds,

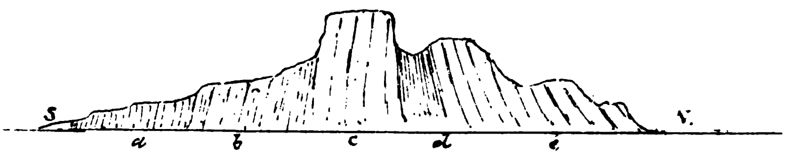


Fig. 3, Sketch Section near Pullasee.

a. Shaley and sandy beds.
b. Purple thick-bedded sandstone-quartzite.
c. Bed of massive whitish quartzite.
d. Shaley beds similar to *a*.
e. Sandstone-quartzite like *b*.

they are of a darker purple than usual, are coarsely rippled in places and dip from 50° to 80° in the same direction as the last. These are superbly seen opposite the village of Pullasee in an island of the Nerbudda, a sketch section (Fig. 3.) of which is given above(b). There are slight evidences of faulting above and below the bed *c*, which is very massive, the beds *b* and *d* near to it presenting a somewhat brecciated appearance, but this is most probably due to slight local dipping. Still *d* and *e* may be repetitions of *a* and *b*, though appearances are not in favor of the assumption. Rippling is seen in all the beds, *c* included. On the north bank of the river, the massive bed *c* can scarcely be traced, although the remainder of the section is perfectly similar.

There appears much doubt if there be any faulting on a large scale in this spot. The beds are suddenly turned up at a high angle, and some contortion, smashing, and local slipping has resulted ; but the vertical shaley beds seen abutting against the breccia, are also seen associated

(a). M. G. S. I. Vol. II, p. 139.
(b). See also M. G. S. I. Vol. II, p. 244, fig. 19.

with similar breccia at the base of the Vindhyans in the Tawa, within half a mile to the southwards. (*a*).

Section near Sakurghat.

From this point the dip to the westward decreases rapidly; the typical purplish, rippled, quartzite sandstones with occasional shaley beds, continue, with a general low dip of 10° or 15° to the north-west, and west-north-west, for many miles. One or two slight rolls in the opposite direction take place, but the dip is, on the whole, pretty steady, till about 3 miles beyond Sakurghat.

Here the river runs in a deep gorge through some magnificent wild scenery, the peculiar greenish water (*b*.) of the river contrasting with the massive purple rocks through which it flows. The beds below Sakurghat are much disturbed, and at least one great line of fracture is crossed, which apparently strikes north-east—south-west. Towards Paimgurh the dip becomes steadier, and the bed of the river expands again, the beds being still quartzite-sandstones; conglomerates prevail near Warangagurh.

Section west of Paimgurh.

West of Paimgurh, the dip changes with a synclinal curve. The highest beds seen here are shaley. The rocks west of the synclinal are softer, but whether they are higher in the series and brought down by a fault, or whether they replace the hard beds of Sakurghat is not quite clear. At Dharee fine shaley sandstones and greenish-grey silty beds, having a glistening surface from the presence of small fragments of mica, are met with; they are thinly stratified, with occasional layers of quartzite sandstone, and coarsely rippled—the ripples in one place were 6 inches apart.

Dharee.

(*a*). These shaley beds were considered by Mr. J. G. Medlicott, 'Sub-kymores'; I am inclined to think them an integral portion of the Vindhyans. I was, however, disposed, on the grounds of mineral resemblance, to class the breccia of this spot and of the Tawa, with the Bijawurs. Mr. Mallet, in his subsequent examination, considered it Vindhyan and he may very probably be correct, for, as seen in the above section, the shaley sandstones occur below the breccia (south of it) as well as above it.

(*b*). The color of the Nerbudda appears different from that of most Indian rivers, and recalls that of glacier-fed streams. It is perhaps heightened by contrast with the red rocks.

From Dharee to Bukkutgurh, the beds undulate, no great thickness being exposed, but a considerable change in colour takes place. The rocks pass down from red quartzite-sandstones into grey quartzite beds, often shaley and flaggy and having frequently a very compact appearance. These beds are often coarse and conglomeritic and contain jasper pebbles. In places they have a peculiarly trappean aspect, as if made up of trap detritus, and they weather into concretionary masses. Below Bukkutgurh the dip is 10° to 15° to the north of east. The trappean-looking beds continue, associated with quartzose and conglomeritic bands, containing pebbles of jasper, red quartzite, and black chert. Markings like annelid tracks occur on the rippled surfaces of the beds. Some oblique lamination is seen.

Bukkutgurh.

Oonkarjee Maharajah.

Fig. 4. The Island of Mandata from the S. shore of the Nerbudda above the Island, distant 1¼ miles.

Below Mandata (Oonkarjee Maharaj), which island consists of these rocks, the typical quartzite-sandstones recur, and form the base of the beds near Burwai; they are massive purplish beds similar to those seen near Chandgurh.

Oonkarjee.

Near Burwai, they rest quite unconformably upon both Bijawurs and metamorphics.

Sections in Gorapachar and Kanyar streams.

In the streams running from the north into the Nerbudda some fine sections of Vindhyans are also seen. There is, however, no object to be gained in describing them in detail. In the Gorapachar stream, just above Peepria and the shrine of Sitabund, and again on the Kanyar stream, south of the halting place known as Andhari-Bagh, the Vindhyans are faulted against the Bijawurs, and the fault, which is a continuation of the same in both places and separates the two formations for many miles, must be of very considerable throw, probably many thousands of feet.

Fault between Vindhyans and Bijawurs at Sitabund, &c.

Vindhyans on Chorul River.

Before returning to the Bijawurs, it is as well to mention the extreme north-west extension of the Vindhyans on the Chorul River, north of Burwai. They here rest upon Bijawurs and extend up the valley for some miles until covered by trap. The Chorul traverses them in a deep gorge, a constant occurrence in streams running through the Vindhyans, and due again to their resistance to atmospheric disintegrating action. In most rocks, the action of air and rain-water disintegrates the surface so rapidly that that surface is swept off and lowered by rain nearly as fast as the surface of the solid rock is ground away by the action of running water and the detritus carried down by it. In such quartzites as the Vindhyans, the chemical action of rain and air are at a minimum.

Formation of gorges in the Vindhyans.

Bulwara.

In the Chorul, east of Bulwara, where Vindhyans replace the Bijawurs in the stream, it is not quite clear whether they are faulted or not, but a little farther north, in the bed of the ravine, a fault distinctly traverses the Vindhyans, and strikes east-20°-north. A mile or two farther up the stream, they are covered up by trap.

West of this no Vindhyans occur in the Nerbudda valley.

To return to the eastern and central part of the Dhar forest and the area occupied by the Bijawurs. The Vindhyans, north-west of Chandgurh, stretch northward till they are overlaid by the trap. The soil resting upon them is red and sandy, with numerous fragments of the quartzite sandstone scattered about; the rock appears here and there at the surface. No sections are seen; the country is singularly devoid of water-courses; and is covered, as usual upon the Vindhyans, with thin tree jungle.

Country north-west of Chandgurh.

The Bijawurs reappear south of the village of Kulree, 12 miles west of Kataphor. The Vindhyans here form the crest of a small ridge known as Tengria hill, scarped towards the south-west, and having a low dip of 1° or 2° to the southwards. The beds are mostly thin and rippled; some of them more of a sandstone, and less of a quartzite than is usual near the base of the Vindhyans in this country. The brow of the hill is formed of thick quartzite-sandstones; these rest upon purple shaley schists, with distinct, nearly vertical cleavage, striking east-10°-20°-north—west to 10°-20°-south. The bedding is distinctly seen crossing the cleavage, and appears to dip to the north-east. Jointing is in two directions, north-east vertical, and about east-10°-south dipping to the north at about 25°. Neither cleavage nor jointing are so well marked as in some slates.

Vindhyans and Bijawurs near Kulree.

This bed clearly belongs to the Bijawurs. In the overlying Vindhyan quartzite, the cleavage of the slates appears represented to some extent by jointing and by small veins of quartz.

At the western base of the hill, in a nulla, vertical bands of veined jasper and hornstone occur, striking east and west, accompanied by sandy and calcareous beds. The relations of these to the slates are obscure.

From this spot to near Katkot the whole country is occupied by the rocks of the Bijawur series. It is a wild jungle, completely uninhabited; the soil upon these rocks, and the Vindhyans being too poor to invite agricultural labor.

Country from Tengria hill to Katkot.

On the road leading south-west from Mansingpoora 2 miles west of Kulree, towards Sitabund and Oonkarjee, vertical states are seen striking north-east followed by brown and reddish sandy beds, containing quartz and hornstone, having a peculiar appearance, and dipping irregularly towards the north. A little further on, in a nulla, close to the halting place called Jharpani, these beds are succeeded by banded quartzite of dark colors, with a little jasper, and, 200 yards further down the stream, by breccia, containing red and grey hornstone and limestone, the matrix, which constitutes by far the larger portion of the mass, being whitish hornstone. These beds roll much, their general strike is east-north-east. Beneath them are limestones, similar to those seen north of Chandgurh, which extend for a long distance to the north and west. They consist of the usual thin, alternating, silicious and calcareous, bands; the hard, silicious laminæ weathering out strongly on the surface, and being frequently crumpled and wavy like the leaves of a book, when compressed from the side, although the general lamination is steady.

Bijawurs, south-west of Mansingpoora.

Jharpani.

South of Tengria hill, and east of Jharpani, there is a considerable development of peculiar soft brecciated beds, somewhat decomposed at the surface. They are doubtless identical with some of those seen on the road from Mansingpoora to Jharpani. They have no appearance of metamorphism, yet contain irregular masses of quartz, similar to those in the lamination of the metamorphics. They also abound in small quartz veins.

South of Tengria Hill.

South of Jharpani, on the road to Sitabund, purplish and pale dove-coloured slates are seen; near them are very fine-grained, hard, shaley sandstones, purplish- or bluish-grey to brown in colour, unaltered and distinctly stratified. Some of the brecciated quartzose rock, so prevalent to the east, also occurs east of the road and north-north-west of Leemonpoor. South of the above-mentioned rocks are some white and dove-coloured talcose slates, and then the typical silicious limestone, of

South of Jharpani.

Leemonpoor.

which, seemingly, a great thickness occurs. All these beds strike steadily to east-10°-north, and are either vertical or inclined at a very high angle to the south.

Section of Bijawurs in Kanyar river above Andhari Bagh.

As already mentioned, these rocks are seen faulted against the Vindhyans in the Gorapachar and Kanyar streams In the latter a fine section of the Bijawurs is exposed between Andhari Bagh, a halting place, and the village of Chundpoora, a distance of 5 or 6 miles. The fault bounding the Vindhyans is crossed a little south of Andhari Bagh, and, at that place, Bijawur limestone of the usual laminated character occurs. A quarter of a mile to the north, there is a singular mixture of this rock with a yellow, sandy, and conglomeritic breccia. Huge masses of each rock occur surrounded by the other. The breccia contains rounded masses of a cavernous quartzite and of black hornstone, and a few of ordinary white or coloured quartzite, (occasionally resembling Vindhyan,) as well as angular blocks of quartzite and limestone. The breccia and the limestone are perfectly distinct, and do not pass into each other, yet they are most strangely mixed together. The blocks of limestone contained in the breccia are smashed and the cracks filled with the yellow sandstone, which forms the matrix of the breccia, and which seems distinctly to consist of grains of sand.

Remarkable breccia.

Lamination of limestone not due to bedding.

The lamination of the limestone, as shewn by the quartzose layers, is much contorted, *and does not appear at all to correspond with the line of junction of the two rocks.* It is thus clearly due to cleavage and not to bedding.

It is difficult to give an adequate idea of this very singular formation. The quartz is partly in contorted and brecciated laminæ, partly irregularly dispersed, partly in rounded masses. In some places, the appearance of brecciation appears due to chemical change, which is exposed by weathering; portions of the beds, being harder and more

homogeneous than the rest of the rock, weather out into angular blocks. The matrix is always the same; a yellow sandstone.

Alternations of this breccia and of the limestone occur throughout the section. The limestone is, as usual, laminated, but not contorted. Occasionally, as in the Tawa, the lamination appears concentric instead of being in parallel planes.

North-west of Andhari Bagh.

North-west of Andhari Bagh, hornstone-breccia occurs, and again in a hill of some height, west-south-west of Andhari Bagh, and south of the deserted village of Mendikhaira. This hill, however, is within the Vindhyan boundary, and as that boundary is a fault of considerable extent, it appears probable that this breccia may belong to the Vindhyans.

South of Katkot.

Further west than Mendikhaira, and south of Katkot, talcose slatey schists, green and purple, are found just north of the Vindhyan boundary. The Bijawurs are then covered up by Vindhyans, which run up the valley of the Chorul, as already described, and the trap comes in upon the Vindhyans in broad patches.

Granite near Mirzapoor.

On the north of this tract of Bijawurs a small patch of granite (protogene) occurs in one of the branches of the Kanyar, near the village of Mirzapoor. It is largely crystallized, and contains chlorite, but no mica. It is overlaid by the sandstones presently to be mentioned, and by trap. This granitic rock only continues for about half a mile down the stream, and is then abruptly succeeded by Bijawur limestones. The junction is not seen, but the limestone, 50 yards from the granite, appears quite unaltered by it, and no veins of the granite are seen in the limestone. It does not appear probable, therefore, that the granite is intrusive, but whether the limestone rests upon it naturally, or whether the two rocks are separated by a fault, it is impossible to say.

Syenite inlier.

Further west a similar small exposure of syenite was seen, but its relations were equally obscure. Possibly, other small patches might be found if close search were made. The position of the two seen along the same line, is rather in favour of their being part of the same area of metamorphic rock, brought up by a fault striking east-north-east.

Traps north of Dhar forest.

The traps north of the Dhar forest are perfectly horizontal, and, in the lower flows at least, very massive and columnar.

Columnar trap dykes.

A remarkable columnar trap dyke occurs about half a mile north of the small village of Pullasee, and about eight miles west of Kataphor. It forms a ridge-shaped rise of no very great extent, the top being a mass of columns inclined slightly to the north. They lie perfectly loose, having been rendered so by weathering, and are very regular in shape, mostly pentagonal or trapezoidal, rarely hexagonal. They average 1 foot to 1 foot 3 inches in diameter. Columns 6 and 8 feet long without a crack abound.

A still more extraordinary dyke intersects the Vindhyans to the north of Dharee, and may be mentioned here. It may be traced for several miles across the country forming a series of elevations. The columns are equally perfect with those in the Pullasee dyke, but they vary in direction, being generally nearly horizontal, but sometimes inclined at various angles, sometimes even perpendicular.

Sandstones along the north edge of Dhar forest.

Between the traps and the Bijawurs, along the north and west of the Dhar forest, peculiar soft sandstones and conglomerates intervene, which increase in amount to the westward. They are not observed to the east of Rattee Talao, though a closer search may shew that they extend farther in that direction. Some sandy travertine-like beds which were indistinctly seen south of Katáphor, and about ¾ mile north of the village of Pora, may perhaps belong to this series, but it appears more probable that they are

interstratified with the traps. As all the ground in the neighbourhood is covered with cotton-soil, the relations of the beds are very obscure.

Near Mirzapoor.

About 2 miles east of Mirzapoor, coarse gritty sandstone is first met with. At Mirzapoor 30 or 40 feet of conglomerate, of a dark colour, is seen resting upon the granite, and covered by trap, which alters the uppermost part into a quartzite. In the Kanyar, a little above Mirzapoor, at Mowripoora, coarse quartzose and fine argillaceous sandstones occur, the former white, the latter purplish and mottled, false-bedded, but apparently dipping at a low angle to the south. These beds are very soft. Some low hills higher up the stream are of the same sandstone capped and hardened by trap.

West of Mirzapoor, the conglomerates and sandstones cover a considerable space along the base of the hills. The pebbles in the conglomerate are mostly of quartzite, some, but not the majority, being of the typical Vindhyan colour. Jasper also occurs in considerable quantities; the beds have much the appearance of Mahadevas.

Near Katkot.

These rocks are traced to Katkot. They may not perhaps be continuous as represented on the map, but they are certainly very nearly so. Around Katkot they spread over a large area, and are met with for four or five miles to the east of the village. Very little rock is exposed, but, in the few sections which occur, soft sandstone or conglomerate is seen, except near the village itself, where some yellowish earthy limestone occurs. South of the village, in some nullahs, fine, soft, brownish, red and cinereous sandstone is seen, somewhat resembling some of the finer sandstones of the Damuda rocks. Clays also occur, mottled or purplish, as in the infra-trappean rocks to the west of Baitool. Near Katkot these clays contain fragmentary carbonaceous markings. All the beds are horizontal, so, probably, no great thickness exists.

There can be little doubt in assigning these rocks to the cretaceous series, so much more largely developed further to the west.

Near Burwai.

Near Burwai in the valley of the Chorul, there are some very interesting exposures of different rocks. Bijawurs, Vindhyans, cretaceous beds, trap and intertrappeans all occur, and metamorphics are found in the Nerbudda about three miles from the town.

The metamorphics in the Nerbudda are faulted against the Bijawurs; hornblend schists belonging to the former, coming against breccia, dipping at 50° to the south-west belonging to the latter. The hornblend schists are striking east-10°-north vertical; these schists contain small veins of quartz and dykes of a trappean rock. This is close to the western termination of the rocky channel, narrowing in places to a gorge, through which the Nerbudda runs from near Hindia; at Burwai the river once more emerges into an open plain and the banks only expose sections of alluvium. The accompanying woodcut, (Fig. 5) from one of

Fig. 5. Gorge of the Nerbudda, near Burwai, from the west.

Mr. Wynne's sketches, gives a view of this termination of the gorge just above Burwai; the prominent bluffs on each side of the river consisting of Bijawur breccia, which is faulted against the metamorphics beyond. Close to this spot it has been proposed to build a bridge across the river. A little further north, on the road from Burwai to Oonkarjee, the hornblendic rocks are succeeded by whitish, slatey schists, with a very different strike, west-15°-north. In these, laminæ and irregular layers of quartz occur as in the Bijawurs.

South-east and south of Burwai all is trap, two or more exposures of intertrappean limestone occur; one in especial, on the left (east) bank of the stream, abounds in *Physa Prinsepii,* both the elongate and the tumid forms occurring.

In the Chorul, east and north-east of Burwai, there is an excellent section of the Bijawur rocks, entirely breccia and limestone of the usual types. Crushing is seen amongst the breccia, precisely as in the Kanyar near Andhari Bagh.

The base of the traps here is very irregular. The cretaceous beds only underlie them in patches; frequently the trap rests directly upon either the Bijawurs or the Vindhyans. A better study of unconformity could not be wished than around Burwai—Vindhyans upon metamorphics and Bijawurs, cretaceous beds upon Bijawurs and Vindhyans, trap upon all four, each unconformable upon the other, though the degree of unconformity varies in each case.

In some cases, a few ill-marked fossils occur in the cretaceous beds.

Fossils in infra-trappean beds.

They are very fragmentary, but broken pieces of shells were found sufficiently marked to show the presence of marine species. About half a mile east of the Chorul on the road from Burwai to Mandata, in a ravine just north of the road, trap is seen resting on a horizontal bed of sandstone and conglomerate, probably calcareous, and much hardened by the volcanic rock. The fracture is peculiar, exhibiting a glistening surface when held in particular directions, as though some mineral (carbonate of lime?) were crystallized throughout the mass. Fragments of an univalve and of a very thick bivalve abound, but no perfect specimens could be found. It is possible that these shells are *Physa* and *Unio,* and that the bed belongs to the trappean series, more probable that the fossils are marine and the limestone cretaceous: it thins out within two or three yards, and the trap then rests upon schists.

At another spot, about a mile north of Burwai and west of the high road to Mhow, there is a considerable inlier of Bijawur beds surrounded by trap. Just west of a small rise of trap, fragments of a reddish fossiliferous limestone were met with, in which fragments, apparently of

an Ammonite and Belemnite, oysters, a small bivalve resembling *Astarte*, a *Terebratula* and fossilized wood, were found—serving to identify the beds as belonging to the Bagh cretaceous series.

Iron ore in Bijawurs.

In the Bijawurs of this same patch, iron ore abounds in a brecciated rock, consisting of irregular fragments of brown hæmatite and quartz in a ferruginous matrix. These supplied ore for some time to the Burwai Iron Works. It is by no means clear, however, whether the ores are an integral part of the rock, or merely the surface impregnated with oxide of iron. The officers engaged in the works were inclined to take the latter view, and the excavations were not sufficiently deep to settle the question.

All to the north and west, for very many miles, is trap. No rocks of older age re-appear till west of Mandoo.

SECTION 4.—NERBUDDA VALLEY SOUTH OF THE RIVER, FROM THE SMALLER TAWA ON THE EAST, TO THE JHERKHUL ON THE WEST, INCLUDING THE BURWANEE HILLS.

Rocks.

The whole of this country, with the sole exception of one small strip in the immediate neighbourhood of the river, between the Tawa and Burwai, consists of trap. The excepted tract is composed of Vindhyans, being a portion of the area occupied by those beds in the Dhar forest.

Granite and infra-trappean limestone near Bijulpoor.

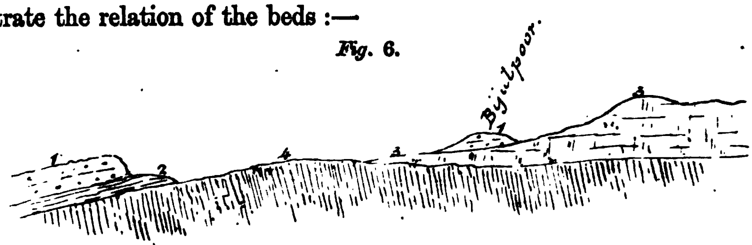
Close to the Tawa, and just south of the village of Bijulpoor, there is a small patch of granite or granitoid gneiss. To the south of it, intervening between it and the trap, is impure nodular gritty limestone, which may possibly be intertrappean, but which appears to resemble the upper limestone of the Bagh beds more closely than any other formation. It contains small fragments of quartz and felspar, besides minute portions of fossil wood. No distinct organisms could be made out, some markings resembling fragments of shells were seen, but their nature could not be determined.

Near Nagpoor.

This bed is also seen at Nagpoor on the Tawa where it is in parts decidedly conglomeritic, containing quartzite pebbles in considerable quantities. In a nullah on the west side of the river, just above Nagpoor, a soft white sandstone with ferruginous conglomerate beneath it, about 1 foot in thickness, and apparently lower in position than the limestone, is seen resting upon metamorphic rocks. This much strengthens the probability of the whole belonging to the Bagh beds.

North of the little patch of metamorphics, and just south of the village of Bijulpoor, Vindhyans come in, and at the village trap occurs. No intervening beds are seen. The sketch section below (Fig. 6) will illustrate the relation of the beds :—

Fig. 6.



1. Trap. 2. Infra-trappean limestone. 3. Vindhyans. 4. Metamorphics.

Vindhyans north of Bijulpoor.

To the north of Bijulpoor Vindhyans re-emerge almost immediately from beneath the traps and rise into hills which continue steadily to the westward. The beds are undulating and resemble precisely those already described on the north bank of the river.

Bagh beds near Poonassa.

Just west of Poonassa near the village of Bhorla, a considerable expanse of ground is covered with sedimentary rocks, apparently of the same age as the Bagh beds, and intervening between the trap and the Vindhyans. At the tank, close to Bhorla, porcelanic clay is seen, probably hardened by trap which is in place close by. Just west of Bhorla, massive nodular grey limestone in horizontal beds crops out on the north side of the road to Taklee. This appears to be higher in position than the clay, and may possibly, in

parts at least, be intertrappean, more especially as blocks of typical intertrappean beds with the usual fossils (*Cyprides* and plant remains) occur near Taklee. The Bhorla limestone contains irregular cherty lumps and fragments of fossil shells in abundance.(a)

To the north of the tank, the ground is covered by black soil. About ½ or ¾ mile north of Bhorla the Vindhyans crop out. Just south of them, and resting upon them, are sandstones and conglomerates precisely similar to those underlying the traps in Dhar forest, and to the beds of Alumpoor, north-west of Baitool. There can therefore be little question about the occurrence in this spot of beds of cretaceous age.

Cretaceous beds formed from detritus of Vindhyans.

Some of the conglomeritic sandstones north of Bhorla have very much the appearance of the Vindhyans, an appearance due to their being composed principally, if not entirely, of detritus derived from those beds. On closer examination the difference is easily seen, the Vindhyans are dense, homogeneous and compact, scarcely a trace of structure being discoverable, while the separate grains of which the cretaceous beds are formed may be distinguished in general with the naked eye. The jungle covering the two rocks also is very distinct. Here, as elsewhere, that on the Vindhyans, is characterized by the absence of underwood, the thinness of the grass, and the prevalence of the Sálee *(Boswellia thurifera)*, which in places is almost the only tree, while the jungle on the cretaceous beds is varied in kind, and both grass and underwood are thick and luxuriant.

Vindhyans north-west of Poonassa.

Vindhyans continue nearly as far west as to opposite Burwai and end close to the spot where they cease on the north bank of the river. A few patches of overlying trap occur upon them. They present no features of interest.

(a). Mr. Wynne obtained marine fossils from Bhorla, but it is not quite certain from what portion of the limestone. It was before the beds of this part of the country were well known. It is clear that both intertrappeans and cretaceous beds occur at this spot.

Remainder of Section.

With the exception of the small tract just briefly described, the whole of the country comprised in this section consists of trap. Near the river, accumulations of cotton-soil, sometimes of considerable thickness, are of frequent occurrence between Burwai and Burwanee. West of the latter town, all the country is very hilly, and the river runs through a deep rocky gorge.

Dip of traps in Nimar and Satpoora hills.

Throughout by far the greater portion of this tract, the traps appear to be horizontal. The exceptions are to the east in Nimar, where they have a low south dip, so small in the neighbourhood of Kundwa as to be scarcely perceptible, and in the Satpoora hills west of Aseergurh. Beneath that fortress itself the beds are horizontal, but in the low hills immediately to the west, there is a strong southern dip, in places amounting to as much as 10° or 15°. This is an exception, but low dips of 2° or 3° prevail largely throughout the range, both on the Khandeish and on the Nimar side.

Volcanic rocks met with.

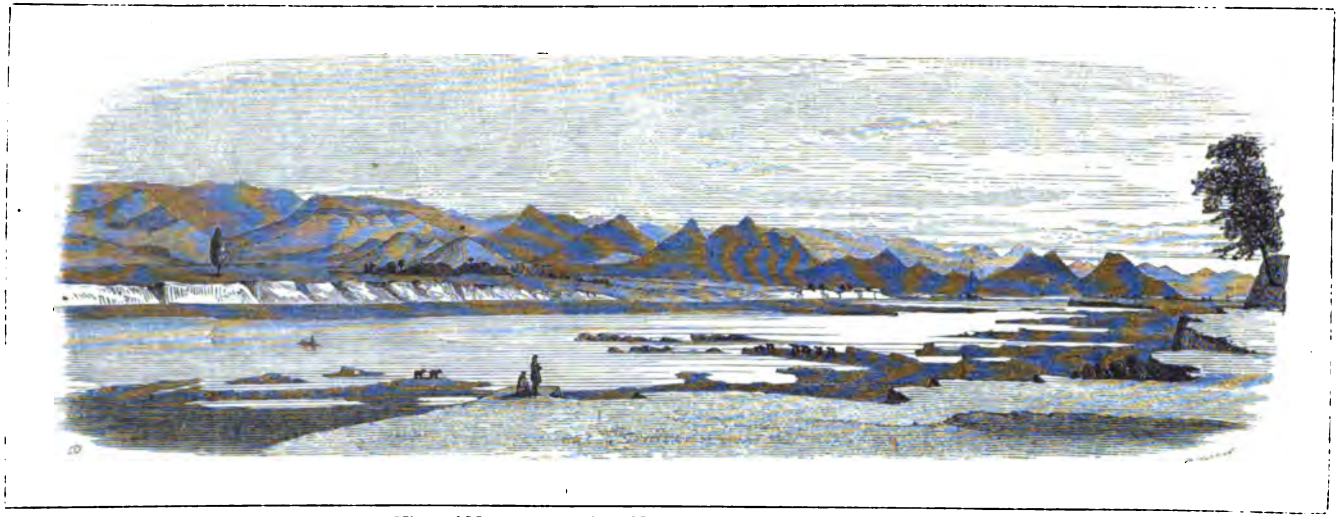
Beds of volcanic ash are of frequent occurrence, and occasional strata of red bole are met with. With these exceptions the whole of the broad undulating plain of Nimar consists of various forms of basalt, usually more or less amygdaloidal. On the railway from Boorhanpoor to the Nerbudda plain, there are no sections of any importance, and very few are seen on the sides of the low hills which occur here and there throughout the country, the surface of the trap being generally much decomposed and concealed.

Burwanee hills.

In the Burwanee hills, which contain the highest hills in the Satpoora range west of Aseergurh, the traps are horizontal. In the valley of the Goi river near Pattee and Sillawud, between the Goi and the Nerbudda, and west of the mouth of the Goi, near the villages of Goongsi, Borkheira and Beejasun, peculiar brecciated veins occur in the traps frequently forming the crests of ridges, which, from their sharp craggy shape, contrast with the usual flat-topped trap hills. This contrast in

Brecciated veins.

Plate 8.



View of NERBUDDA *above* HIRUNPALL, *looking down the river.*

outline is well seen just above Hirun Pall, looking down the river (see Plate VIII). The massive flat-topped trap hills of Burwanee on the left of the view and the ridges due to the brecciated veins just noticed on the right. The breccia in these veins is usually highly calcareous; all have nearly the same direction east-10°—30°-north, and they are probably due to small faults.

Toorun Mul.

The hill of Toorun Mul believed to be the highest of the Satpoora (*a*) has a table land upon the top of considerable length, but of no great breadth, as is frequently the case with the trap hills. This spot was formerly used (as a retreat during the hot season in all probability) by the rulers of Mandoo, and a splendid piece of water still exists about three-fourths of a mile long. This tank, for such it is, is clearly retained by an artificial bund of considerable size. An idea, however, commonly prevails that the hollow containing the water is an ancient crater, and to a report of its existence is probably due the statement in Captain Dangerfield's Appendix to Sir John Malcolm's 'Central India' of the supposed existence of craters in the Rajpeepla hills. (*b*)

Tank on Toorun Mul.

SECTION 5.—COUNTRY AROUND BAITOOL WITH THE UPPER TAPTEE VALLEY. FROM THE EASTERN BOUNDARY OF THE MAP TO BOORHANPOOR, AND FROM THE DIVIDING RANGE SOUTH OF THE NERBUDDA TO THE PLAINS OF THE POORNA IN BERAR, INCLUDING THE GAWILGURH HILLS.

Area included.

This section consists principally of the upper drainage area of the Taptee, as distinguished from that of its great affluent, the Poorna. A small portion of the country drained by the tributaries of the greater Tawa, and therefore within

(*a*). It is nearly 4,000 ft. in height. The aneroid at 3 p. m. on April 12th, 1864, stood at 26·8, thermometer 83°.

(*b*). Vol. II, p. 325. See ante, p. 7.

the Nerbudda watershed, is also included. To the east and north the country is comprised in Mr. J. G. Medlicott's map in Vol. II of these Memoirs, which bounds the northern parts of the present area, while further south the boundary is that of Sheet 54 of the Indian Atlas.

Rocks.

All the southern and western portions of this area are of trap. Around Baitool, and for some distance west of that town, infra-trappean rocks are met with.

Topography and geology of map only approximate.

Although many parts of the map appended are deficient in topography, this tract near Baitool is especially inaccurate. No topographical map had ever been made, and time did not allow of a sketch map being constructed, except one so rough as to be merely an indication. The geological lines are therefore only the very roughest approximation.

Country near Baitool.

The extreme north-east corner of Atlas Sheet* No. 54 is in the Tawa valley, within Mr. Medlicott's map. South of this is a belt of high ground upon which Baitool stands. To the north this is composed of metamorphic rocks: to the south all is trap.

The boundary of these rocks from Amla to Sohagpoor and thence westward south of Baitool is natural and not faulted. Its features are well marked, the traps rising in a continuous range, flat topped, as usual, to the south, while the very granitoid metamorphics either occupy a level plain or form isolated hills and short ranges. Upon some of the latter, outliers of trap occur, but they are of no great size. At one spot there is a small patch of conglomerate between the base of the trap and the metamorphics.

Gneiss, rather less granitoid than further east, but still highly crystalline, forms the hills stretching across to the north of the civil station of Budnoor. Some crystalline limestone was found in them,

* This portion is blank in the Atlas Sheet.

but it was so much intermixed with felspar as to be useless for burning into lime.

Plain of Baitool.

The highly cultivated plain of Baitool is composed of a thick alluvial deposit, entirely devoid of black soil.* It is traversed by the upper portion of the Machna river, a tributary of the Tawa. The range of low trap hills already mentioned bound this valley to the south, and form, in fact, the parting ridge between its drainage and that of the Taptee.

Trap hills south of Baitool.

Along this low scarp the beds of trap are, in part, horizontal, in other places they have a very low southern dip. For some distance along the range there is a bed, and in places, probably, two beds of intertrappean sedimentary deposits abounding in fossils. The most eastern locality where this is seen is east of Bayawadi; beyond that to the eastward the intertrappean band probably thins out. An unfossiliferous calcareous mass was met with near Khappa, still further east, but it was at a higher level, and, if belonging to an intertrappean bed, must have been part of a distinct stratum from that seen at Bayawadi. About Sohagpoor and further east no trace of any intertrappean bed could be found.

Intertrappeans.

The fossiliferous bed is best exposed near the village of Loharee, and on the sides of the road from Baitool to Dholun and Mausood. At the top of the Ghat, upon this road, there are many scattered fragments containing shells, wood, cyprides, &c., but no bed is seen in place. On the face of the hill, however, a few feet below the top, there is a bed scarcely distinguishable in mineral character from the trap, from the debris of which it appears to have been composed, but abounding in fossils, especially *Physa Prinsepii, Lymnea, Paludina, Valvata,* and plants. Lower down there is a thin band of very silicious rock, resembling

* This is one of numerous instances in which the boundary of the traps is the boundary of the black soil also. See the Chapter devoted to soils; ante p. 72.

hornstone, also abounding in shells. It is not quite clear that this bed is distinct from the upper one, but it has much the appearance of being so, and it is highly probable that the fragments found on the top of the Ghat are from a still higher bed.

The principal sedimentary band was seen in place at Soorgaon, and traced by fragments further. The same, or another occurs also south of Keiree, on the road leading south to the Taptee (the Baitool and Ellichpoor road), and again south of the river, near the top of the Ghat ascending to the table land. It abounds in fossils everywhere.

Dip of traps south of Baitool.

The traps south of Baitool are mostly horizontal until the neighbourhood of the scarp at the verge of the Berar plain. The characters of the beds of that scarp will be best described hereafter in treating of the Poorna and Wurda vallies.

West of Baitool.

To the west of Baitool the metamorphic rocks disappear gradually beneath the trap, not being all covered up at once as to the south, but stretching in vallies far within the trap hills. Between the two series also in this direction conglomerates and sandstones are met with, which represent similar beds in the Dhar forest and elsewhere, and are almost certainly representatives of the Bagh beds.

Infra-trappean sandstone north-west of Baitool.

Commencing north-west of Baitool, the sandstone represented on the very edge of Mr. Medlicott's map near Koprabanee is about 100 feet thick, coarse and conglomeritic in part, and resembling that on the top of Ruttunmul hill, north of Chota Oodipoor, and that of the Dhar forest. Like them it contains small pebbles of red jasper. It forms, near Koprabanee, a small plain on the top of a rise of metamorphic rock. It is represented by Mr. Medlicott as Mahadeva, a circumstance which is in favor of the identification of that formation with the cretaceous beds of Bagh.

At Chiklee, south-east of Koprabanee, there is no sandstone at the site of the present village, and trap rests directly upon the metamorphics. Just south, however, at the old site, the sandstone recurs, and extends away to the south towards Alumpoor, east of which village it becomes much thicker, and covers a tract of country extending for about three miles along the Chicholee and Baitool road. Very little, however, is seen at the surface. A well at Alumpoor, sunk just south of the road, passed through a few feet of trap, and was then dug for at least 25 feet through argillaceous sandstone, bright brick-red in colour, but in part mottled with white and lilac. The greater part of the sandstone is coarse and conglomeritic, but argillaceous bands, red or purple in colour, occur occasionally.* Some of the sandstones are hard, massive, and white in colour, like those of Salbaldee in Berar. The whole thickness must be considerable. South of Alumpoor the boundaries of all the rocks are far more intricate in reality than they are represented on the map, which, as before remarked, is only a rough approximation. The areas of sandstone and metamorphics are, in reality, dotted over with outliers of the higher formations, and the lower beds are exposed frequently within the main boundary of the traps.

Chiklee.

Alumpoor.

South of Alumpoor.

There must be a great thickness of sandstone in the valley of Khattapani and Khamapoor. The beds are massive, but still distinctly bedded, and have a general dip to the south. On the hills south-west of Khattapani a comparatively thin band of horizontal conglomerate is alone met with. This is in favor of the Khattapani sandstones being something distinct.

Khattapani.

Similar beds to the last, and with the same close resemblance to the conglomerates of Chiklee, are traced between the traps and

* It is possible that these rocks may be the same as those of Kamptee near Nagpoor.

metamorphics south of the Taptee. They are constantly conglomeritic, containing pebbles of various coloured quartzites, red jasper, &c. They are not felspathic, nor do they contain calcareous or ferruginous concretions. At Boree, close to the road leading through Jeen to Keiree, some of the sandstone is so much mixed with silica as to be in part converted into chert. This has been shown to be a common character in the Bagh and Lameta beds.

Inlier in Taptee.

There is a peculiar inlier of metamorphics and sandstone exposed in the Taptee south-west of Baitool. To the north about Chiklee, Alumpoor, &c., the traps are horizontal, but they roll over to the south just north of the river, and the lower rocks are, for the most part, concealed by them. The Taptee, however, runs in a deep narrow gorge, in the bottom of which the infratrappean rocks are exposed again. At the eastern extremity, which is near Keiree, no sandstone occurs, but a few miles to the west it comes in, and continues to be exposed further to the west than the metamorphics are. On the road from Baitool to Ellichpoor this trough of metamorphic rocks is crossed, and the base of the trap south of the river appears to be decidedly lower than to the north, showing the sharp southern dip of the base of the traps. Here the river runs from east to west, but a little higher up it runs from the south, and, just above the turn, the traps alone occur in the river bed, the top of the metamorphics having dipped under them.

Sandstones in Taptee Section.

Some fair sections of the sandstone are seen in the Taptee. The beds appear to vary much in thickness. About Chuna they have a considerable vertical development; a little farther to the west they must be much thinner. The beds are in general compact, often very hard, white or brownish in colour, and occasionally of various shades of red, the uppermost beds especially being often variegated with different tints, red, orange, and brown. Near Ratimati soft argillaceous beds occur of a

bright brick-red colour, resembling the uppermost seen in the well at Alumpoor.

Rocks in Taptee, from Melghat to Boorhanpoor.

The sandstones end out about 20 miles above Melghat, and no beds from beneath the traps emerge thenceforward throughout the whole course of the Taptee. The bed of the river from Melghat to Boorhanpoor presents no peculiar geological interest. Basaltic columns occur in two or three places near Melghat, and they appear to be as common here as they are in the lowest beds of trap beneath the Malwa plateau. These Taptee beds must also be amongst the oldest of the lava flows. Some of the best basaltic columns are seen about two miles above Melghat, and again lower down near the small village of Hurda.

Passing down the river, alluvium begins to be found in considerable quantities near Sindwal, and to form a large proportion of the river's bank. It gradually increases in amount and covers more of the adjoining country. Still there is no continuous alluvial plain along the river till near Boorhanpoor. The alluvium presents the usual characters.

Hills north of Taptee.

The hills north of the Taptee between Melghat and Boorhanpoor are of no great height. They consist entirely of trap. The great Gawilgurh range between the Poorna and the Taptee is entirely composed of basaltic rocks. The beds along the southern border dip to the north; the features of the scarp will be noticed in the next section. Near the Taptee the dips, when any are seen, are to the southward. Only the verge of these hills was examined, but in the streams running from them none but trap pebbles could be found.*

Gawilgurh range.

* There was one exception: in the Sipna Nuddi close to its junction with the Taptee, I found a large unrolled fragment of quartzite, five or six inches across. As I could find no more, and no rolled pebbles occurred, I do not think any quartzite can be in place in the valley of the stream. There is no quartzite known anywhere near the spot except the fragments brought down by the Taptee, and I am at a loss to account for the occurrence.

SECTION 6.—THE POORNA VALLEY WITH A SMALL PORTION OF THE WURDA VALLEY, BEING THE SOUTHERN PORTION OF SHEET 54 OF THE INDIAN ATLAS.

General description.

This section, as regards area, is one of the largest of all, but its geological interest is scarcely in proportion to its size. It embraces the greater portion of the districts of East and West Berar and, on its extreme eastern edge beyond the Wurda, a very small strip of the Nagpoor district in the Central Provinces. By far the largest portion of the area is composed of the great alluvial plain of the Poorna, bounded on the north by the escarpment of the Gawilgurh hills, and on the south by the trap rises which lead to the Deccan plateau, and which, to the westward, near Adjunta, rise much more abruptly than they do further to the east. The only other hills occurring in this tract are a small mass of no great height, south-east of Oomrawuttee.

Alluvial plain of Poorna.

The alluvial plain of the Poorna, though not equal in length to that of the Nerbudda above Hoshungabad, exceeds it in width, being 40 miles across where broadest.* The boundaries of the alluvium cannot, of course, be laid down absolutely, since there is, in all such cases, a gradual passage from a tract completely covered by clays and gravels to one partially covered, in which the underlying rocks begin to appear here and there in stream sections, wells, &c., and from this again to rocky ground. The boundary has been drawn approximately where rock commences to be seen in the streams and hollows.

South scarp of Gawilgurh hills.

Besides the features of the low country, those of the southern scarp of the Gawilgurh hills may also be included in this section. It is along the base of this range alone that any rocks of older date than the traps appear within the area of Northern Berar, and the rocks seen amount only to a few isolated inliers in the north-east corner of the Poorna valley. They

* The greatest breadth of the Nerbudda plain is about 35 miles.

will receive attention first of all, both on account of their position and of the interest attaching to them.

Sandstones, &c., north-east of Ellichpoor.

The main portion of the scarp throughout is, of course, of trap. East of Ellichpoor, however, when looking towards the hills from the southwards, while the higher portions present the flat tops and marked terraces, and are covered by the dried grass and thin tree jungle so characteristic of the traps, a fringe of lower rocky hills, much darker in colour, and covered with tree jungle, bamboos, &c., is conspicuous in the foreground. These hills are composed of sandstone (Plate 4). Their southern boundary is a fault, evidently of considerable size, immediately south of which trap re-appears throughout. In one place metamorphics occur north of the principal fault, but apparently themselves separated by a fault from the sandstones, the base of which is not seen anywhere.

Near Mankapoor, &c.

These sandstones are first met with to the eastward close to the extremity of Sheet 54 and of the present map.* A narrow strip of beds, much tilted up and indeed nearly vertical, only 50 to 100 yards in breadth, occurs for a mile along the fault, north-east of Mankapoor. They are then not seen for a short distance, but come in again about half a mile east of Koomdurra, and are here somewhat broader and less disturbed. After about a mile they are again cut out, but re-appear after a short interval just east of Thullotee, and thence extend for several miles to the westward.

A fair section of these sedimentary beds is seen near Dhabka, in a stream running past that village and Thullotee.

Section near Dhabka.

The topmost bed is the usual calcareous sandstone with cherty blocks, so typical both of the Lameta and Bagh beds. Beneath this is a fine white or greyish felspathic sandstone. Each of these beds is between 4 and 5 feet thick. The next bed in descending order is an impure earthy, rather gritty sandstone, greenish in colour, abounding in irregular lumps and nodules

* The country further to the eastward was not examined, and it is not known if any more exposures occur in that direction.

of quartz, so that a weathered surface resembles granite at the first glance. This is a very massive bed, very argillaceous in parts, about 30 feet in thickness. At the base are 6 or 8 feet of a peculiar mottled ferruginous sandstone, green and red in colour, the red portions chiefly composed of peroxide of iron, and having a distinctly concretionary structure. The green portions and the sandstone above are probably coloured by silicate of the protoxide of iron, perhaps a form of green earth derived from the traps by percolation.*

Beneath the above described beds there is a great thickness of coarse compact sandstone, white in colour generally, with occasional brown and reddish bands. The beds are, for the most part, more or less felspathic, or, to speak more correctly, argillaceous, for the interspersed grains which were, in all probability, originally felspar†, have decomposed into clay, as is commonly the case in the Damudas. Some beds are so coarse as to form grits, others are conglomeritic. Trap, doubtless intrusive, occurs somewhat irregularly, and not in well defined dykes. These sandstones continue to the southern fault by which they are tilted up against the traps. The section altogether is about ½ mile long; if the average dip be considered to be 12°, which it is very nearly, the approximate thickness must be 500 feet.

Gordo.

Near Salbaldee.

Passing to the westward, the band of sandstone increases in breadth, and rises into hills. At Gordo, the characteristic calcareous cherty bed is again conspicuous at the top, and the same occurs again north of Salbaldee. At the latter place, the Maroo river issues from the hills, and the sandstones are well seen in the gorge through which it flows.

* It appears very probable that these upper beds represent the rocks immediately beneath the trap near Nagpoor, which in their turn exactly resemble the Lameta beds of Jubbulpoor. The relations of the lower rocks of Dhabka, Salbaldee, &c., have been treated of before, Part I, Chapter 9.

† It would, however, scarcely be correct to term such sandstones simply argillaceous sandstones. In the latter the clay is generally dispersed throughout the mass, not collected together as when it results from the decomposition of felspar. In this case the rocks are truly originally felspathic sandstones.

They are the same white and occasionally brownish compact sandstones, conglomeritic in places, which are seen at Dhabka. The beds are very massive, and obliquely laminated to a great extent. Ferruginous bands are common, and beds of shale occur, white and lilac, and occasionally deep purple in colour, and containing obscure plant impressions.* Near their southern border they dip at 15° or 20° to north-north-west, but the inclination gradually diminishes to the northward. The trap dips at a lower angle in the same direction. There is certainly unconformity: in the Maroo, traps, dipping at 5°, rest upon sandstones dipping at very nearly 15°, but part of the apparent difference may be due to the gradual diminution of the dip to the northward. The constant occurrence of the calcareous bed at the top of the sandstone, on the other hand, looks like conformity between these beds and the trap. It is, however, highly probable that the traps and these calcareous beds may be conformable to each other, and that both may be unconformable to the sandstones below. At the time that the beds were surveyed, no such unconformity was suspected nor searched for, but it is a question worthy the examination of some future explorer. As has been already remarked, it is highly probable that while the calcareous beds are Lameta or Bagh, the sandstones below represent the rocks of Kamptee.

Unconformity of traps on sandstones.

High dip in traps.

Near Gordo the dip of the traps is as high as 10°, and in one place even 15°. This is near the fault, which is evidently, in part at least, of later date than the traps.

Metamorphics at Salbaldee.

Outside the base of the hills at Salbaldee, there is a narrow band of metamorphic rocks faulted on both sides; on the north against the sandstones, to the south against the traps. The general strike of the foliation is the same as that of the fault at Salbaldee east-north-east to west-south-west, which is also the direction of the great faults in the Nerbudda valley. The

* There is a decided resemblance between these rocks and those of Bazargaon near Nagpoor.

most remarkable circumstance, however, about the fault at Salbaldee is that it is a reversed trough fault, for although the two faults unite a few miles to the east and west, so that they can only be considered as a part of one general fault, they throw in different directions. Such a phenomenon can only be explained by supposing that throws have at different times taken place along the same line of weakness, but in different directions, up and down, and that in this place the two lines have not exactly coincided, though elsewhere they have. (Fig. 7).

Peculiar fault.

Fig. 7. Sketch section of the rocks at Salbaldee. 1, traps: 2, calcareous beds: 3, sandstones: 4, metamorphics.

From the metamorphics, close to the fault at Salbaldee, a hot-spring rises, the temperature of which is 100° Fahr. The water is clear, tasteless and scentless.

Hot-spring.

The metamorphics, as already stated, continue for only a mile or two in either direction from Salbaldee, and their breadth is very small indeed, though its exact amount is not clearly seen. Along the fault to the eastward, there is a mass of highly crystalline trap, resembling a dyke, and it appears probable that a dyke has been in places injected into the fault. Some dykes also cut through the sandstone.

Area of metamorphics.
Trap in fault.

In the next valley* to the westward, about 3 miles from Salbaldee, the sandstone appears to be about 300 feet thick, and is capped by the silicious limestone varying from 15 to 30 feet in thickness, and occasionally containing pebbles. Here also

West of Salbaldee.

* All the details of the sandstones and of the scarp west of Salbaldee, together with nearly the whole of the Poorna valley, are from Mr. Wynne's notes.

the trap, although dipping to the north, appears to do so at a lower angle than the sandstone. A little to the west of this, on the slope of a high trap hill called Mahakul, an intertrappean silicious bed of small thickness, not more than 1 to 2 feet, was met with.

Western extremity of sandstone near Nurha.

The same characters are exhibited throughout this patch of sandstone which extends as far as Nurha. Towards the western extremity, the trap, south of the fault, rises into hills of no great height, the beds on which appear to be horizontal. This is near the village of Chicholee. Almost at the very end of the sandstone, close to Nurha, a stream traverses the beds, and exposes a somewhat peculiar section, in which trap, limestone and sandstone alternate. Apparently some dykes or irregular intrusions, perhaps accompanied by faulting, have penetrated and disturbed the beds. The limestone has a brecciated appearance, and contains green silicious bands.

Indications of sandstone west of Nurha.

At Nurha the sandstone disappears beneath the traps. About 3 miles to the westward there are some small craggy hillocks covered with blocks of sandstone and limestone. In one spot these rocks appeared to be in place, but all around trap was seen. This is doubtless on the line of the fault, but it is not quite clear if the top of the sedimentary beds here rises to the surface, or whether the masses seen are merely fragments included in the fault.

Sandstone near Karinja and Belkera.

With this exception, if it be an exception, no sandstones are brought to the surface for 16 miles. The traps north of the fault have a north dip of about 5°; the course of the fault being more nearly west than west-south-west. Towards Palla north-west of Seerusgao they turn up and dip to the east of north, and, brought up by this eastwardly dip, the infra-trappean rocks re-appear north of the village of Karinja, and extend for about 6 to 7 miles, being cut off on the south by a fault, just as in the more eastern patch. The mineral

character also is similar. North-west of Karinja about 200 feet of the white sandstone, conglomeritic in places, is exposed, dipping at 15° to 20° to the north or north by west.

Calcareous accumulations on line of fault.

In several places in the traps, chiefly along the line of the fault, are considerable accumulations of calcareous rocks as at *a* in the accompanying sketch section

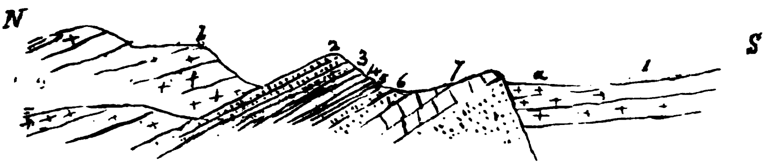


Fig. 8. Sketch section of beds near Belkera.

1. Trap.
2. Sandstone.
3. Flags and purple and white shales.
4. Limestone.
5. Shale.
6. Sandstone.
7. Limestone.

taken to the east of Belkera (Fig. 8). These masses of impure limestone are quarried for burning into lime by the natives. They are also found further east near Palla and Byram.

Section near Belkera.

The sketch represents the general section of about 300 feet of infra-trappean beds near Belkera. Just south of the fault are the calcareous rocks mentioned, the line of fracture itself is indicated by a low rocky ridge of limestone. Above this, sandstone is seen, followed by flaggy shales, red, purple, grey, and whitish in colour, with obscure plant impressions. Upon these rests a bed of silicious limestone, and on that again other shales of various colours, deep purple, greenish and grey, some of them having a very great similarity to trappean ash, others being calcareous. With these are cherty sandstones, and nodular limestone like that of Bagh.* In

* Mr. Wynne, from whose notes of the rocks this is copied, calls this "earthy lumpy limestone weathering into lumps, as seen often in the country west of Bagh," which gives a very good idea of the rock. Near Bagh it has much the appearance of a bed formed of consolidated kunkur, rather freer from clay than usual. A precisely similar bed occurs at Lameta Ghat near Jubbulpoor.

GLEN. S.E. OF. CHIKULDA.

GAWILGHUR FORT IN DISTANCE

Photozinco. at the Surveyor General's Office,
Calcutta, August 1868.

one of the latter a few shells of ***Melania*** were found. The uppermost bed is a hard coarse sandstone, which dips below the trap.

West-north-west of Belkera, in a similar section, more of these shells occur. Besides the ***Melania***, (which is allied to ***M.*** *quadrilineata*, Sow., but differs in sculpture) a small bivalve, apparently a *Corbicula*, is found. These fossils are only met with in the upper portion of the beds, those which appear to represent the rocks of Bagh and Lameta.

Southern scarp of Gawilgurh range.

Before returning to the eastern edge of the map, a few words on the range of the Gawilgurh hills west of this may be added.

The sandstones die out just north of Ellichpoor, and thence to the westward trap hills appear to rise both north and south of the line of fault; the former, however, being by far the higher, and rising at Chikulda to 3,775 feet above the sea, while one peak a little further west is 3,975 feet above the sea, or about 3,000 feet above the plain of the Poorna valley.* The fault itself cannot be traced with clearness further to the west, but that the line of disturbance, very possibly accompanied by a throw of the beds, stretches along the south scarp of the hills, is proved by the steady dip of the traps to the north along that line, a dip which only continues for a few miles to the northwards. The hills gradually diminish in height to the west. Along their base or at no great distance the alluvium comes in, being very much more stony and gravelly in their neighbourhood, as might be expected.

Chikulda.

On the top of the range, at Chikulda, (see Plate 5) the soil is red and lateritic looking, but no absolute laterite was met with so far as the hills were explored.

Chichari.

At Chichari, north-east of Jamod, a vein of calcareous breccia, striking north-10°-east and underlying 80° to the westward, was seen. This is like the veins in the Burwanee hills, and perhaps denotes a small fault.

* The heights from the map of the Topographical Survey.

West of Rajoora.

West of Rajoora, small parallel ranges flank the main range of hills, but they are not continuous for a long distance. Near Burgao the main scarp has been cut back for a considerable distance, the massive bed which, in this neighbourhood, caps the range, having been removed by denudation except on a few isolated summits.

Northerly dip.

Almost to the termination of the range, the same northerly dip is to be seen along its southern scarp. Indeed it is higher than to the eastward, being frequently 10° to 12°.

Alluvial plain of Poorna valley.

South of the Gawilgurh range is the great plain of the Poorna. It presents only one peculiarity to distinguish it from the similar plains of the Taptee and Nerbudda, that is, the existence of large quantities of salt at a considerable depth in the alluvium throughout a portion of its area, extending from the neighbourhood of Dhyunda, north of Akola, till within a few miles of Oomrawutee. Wells for the purpose of obtaining brine are sunk on both sides of the Poorna, always to a great depth. The upper clay contains very little or no salt :* occasionally carbonate of soda forms an efflorescence upon it, but the chloride of sodium is all obtained from beds below the gravels and calcareous conglomerates. Near Dhyunda the deepest wells are about 120 feet; the section in them could not be seen, as the wells are small, and cased with wicker work, but the section was by the natives stated to be—

Salt in alluvium.

Sections in brine wells.

1. To a considerable depth, ordinary brown alluvial clay.

2. Yellow sandy clay.

3. Reddish clay.

4. Gravel and sand of varying thickness, with a ferruginous appearance.

5. Tenacious gravelly clay. This is the saliferous stratum; on tapping it (? boring through it) salt-water rises with great force.

* The shallow wells, however, are in places brackish.

No fossils were observed in the earth thrown out from the wells. Old workings are scattered over the country and serve approximately to indicate the extent of the salt-bearing stratum.

Wurda valley.

Returning now to the extreme eastern edge of the map, a small portion of the Wurda valley will be found included in the present section. Much alluvium occurs here also in the immediate neighbourhood of the river, and presents precisely the same characters as in the valley of the Poorna, except that the salt-bearing beds are not known to exist. But this alluvium is not continuous over any very large area; trap is seen every few miles in the river bed, and it has not been necessary to distinguish the tract occupied by alluvial deposits on the map.

Fossil bones and teeth.

In the gravels below the clay a few bones and teeth were found, as in the Poorna valley, but in both cases they were exceedingly rare. At Buttoda, on a small stream called the Changur, a tributary of the Wurda, two interesting teeth were found. One was the first premolar of the right lower jaw of a horse, the other the canine tooth of some very large carnivore. It exceeds a tiger's tooth in size, and almost equals *Machairodus*. Unfortunately the termination and the inner edge being imperfect, it is impossible to say whether it be ursine or feline.

Watershed of Poorna and Wurda.

The watershed between the Wurda and Poorna is mostly low (except south-east of Oomrawuttee), and consists almost solely of trap, nearly horizontal.

Laterite near Rithpoor.

Two small tracts of laterite, however, are met with, one just south of Rithpoor, the other about four miles north of Oomrawuttee. The latter is the largest and best exposed, some good sections of it occurring in the river bank. Above, it is gravelly in texture, consisting of the usual small ferruginous grains in a red matrix; the grains when broken showing concentric structure. Beneath, it is more compact, but soft. In one place it was seen to rest

on greenish-grey mottled mudstone, breaking into small cuboidal fragments, with joint surfaces between, so minute that it is impossible to obtain a fair fracture. This is probably decomposed trap.

Hills south-east of Oomrawuttee.

There is a low range of hills south-east of Oomrawuttee formed of horizontal beds of trap. A low south-south-west dip was observed in one spot alone, near the village of Karla. Upon these hills, about two miles south-west of the civil station at Oomrawuttee, three or four very small caps of laterite occur. They are similar to that found in the plain, but more compact, and would be useful for building. They have every appearance of being detrital in origin, and very possibly formed from the detritus of other latreite.*

Plain south of hills.

South of these hills is an open trap plain, through which the railway from Bombay to Nagpoor passes. It presents no peculiarities.

SECTION 7.—NORTHERN PART OF KHANDEISH FROM BOORHANPOOR TO CHICKLEE.

Nature of country examined.

Khandeish has only been examined as far south as the river Taptee. The northern portion of the district consists of a strip of variable width between the river and the Satpoora hills, chiefly covered by alluvium. Trap, the only other

Wanton destruction of the forests in Berar.

* These hills south of Oomrawuttee are an example of the wanton destruction of the forests which is taking place throughout Berar and in many other parts of India. A few years ago, they were covered, it is said, with fine trees, now nothing remains upon their slopes but the most insignificant scrub. Springs and streams used to exist; they have entirely dried up. The cleared land is in great part of no use, a portion is employed as pasturage, but its value in this respect is not increased to any great extent by the destruction of the trees, and there was ample pasturage before, as there always is upon the trap hills, for the requirements of the population. Only a very small portion of the soil is used for agriculture. The majority is a waste, utterly useless, and rapidly passing into the condition of so many of the hill sides in the Deccan, rocky barren rises with all the soil swept off them by rain, while the railway running past the base of the hills is, on account of the scarcity of fuel, worked with coal brought from England! Can nothing be done to teach the natives of the country how profitable it would be to grow wood, as is done in every civilized country in Europe?

formation met with, forms the hills, and appears here and there in the deeper ravines cut through the alluvium.

The bed of the Taptee itself was not examined, and the Satpoora hills were only traversed here and there. It was clearly ascertained that no infra-trappean rocks occur in them by carefully examining the pebbles in the different streams running from them. Trap may occur in the bed of the Taptee here and there, as it does in the Nerbudda, in the plain near Mundlaisur, and this is the more probable in the former river, because rises, formed of the rock, approach to within no great distance of the stream every here and there on the south. There is rock near Bhosawul, at the spot where the railway bridge crosses the Taptee, although alluvium extends for some 15 miles to the north.

Very little needs description in this section: for the few remarks required, it will be most convenient, as in other sections, to commence to the east at Boorhanpoor* and proceed westward.

Country near Boorhanpoor.

Below Boorhanpoor very little rock is seen in the Taptee. North of the town there is thick alluvium, but a little to the west trap comes in. On the north, on the road to Asseergurh, trap is met with. About 5 miles from Boorhanpoor, near to this spot, a little east of the road, and about a mile north-east of the village of Choolkhan, there is a singular patch of limestone.† It is compact, but shows no signs of crystallization, and it appears to contain no fossils. It is quite isolated, all around being trap, and about 50ft. in length. At one end of it, there is a white sandy rock, resembling decomposed gneiss in appearance, and standing on end, as if it were part of a vertical bed; it however contains rounded grains and is probably sandstone. Some red clay is associated with it.

Limestone and sandstone near Choolkhan.

This mass of sedimentary rocks is evidently a portion of some infratrappean formation, very probably Lameta or Bagh, either brought up

* The authorities of the Great Indian Peninsula Railway miscall this place *Boranpur*.

† This was pointed out to me by Mr. Naher, Assistant Commissioner of Boorhanpoor.

by a dyke or included in a lava flow, like the granite in the river bed at Mundlaisur*. As frequently happens, the rocks around are not sufficiently well seen to prove which of these is the case, but there is no evidence of a dyke.

Traps near Aseergurh.

The traps in the hills around Aseergurh are not horizontal, but dip very irregularly, and the same is the case for a long distance to the west. At a considerable distance south of the main range, there are low rises stretching across from Boorhanpoor to near Ravere. The traps in them appear to dip north at about 5°.

Hot-spring near Arawud.

North of Arawud, at Onabdyo, a hot-spring breaks out at the foot of the hills, just at the point where the trap crops out from beneath the alluvium. Like in the hot-spring at Salbaldee in Berar, the water is tasteless and scentless. The temperature cannot be easily determined, as the spring issues in a large pool, bricked round. The temperature of the pool was 90° in May; that of the spring, however, was certainly higher.

Dip of traps.

North of Chopra, in the Amnair valley† and around Dowlait, the traps appear to be nearly horizontal, and the same is the case to the westward as far as the Bombay and Agra road. On that road at the top of the ascent leading to Sindwa, the beds are in distinct horizontal terraces. A few miles further to the north, they have a low dip of 2° or 3° to the northward.

Near Sultanpoor.

The alluvium runs far up between the hills about Sultanpoor in a deep bay. Low hills bound this bay to the south, and amongst them, near Waria, north of Warool, are a few trap dykes striking east-15°-north to west-15°-south, as in the

* See next Section.

† The published maps of this part of the country are very inaccurate. That herewith issued is a mere sketch, especially to the eastward, except where copied from Major Baigrie's map.

Rajpeepla hills. North of this again a high dip is seen in the traps, 10° and 15° to north-15°-west, and a similar dip occurs further west to the south of Sultanpoor.

Hills near Akranee.

North of Sultanpoor, the hills rise from the plains in flat mural ridges of no great height, but they gradually increase in size to the westward, till they culminate in the hog-backed masses around Akranee fort. So far there has been an apparently low eastwardly dip from near Sultanpoor*. About Akranee, the northern dip commences, which continues throughout the southern portion of Akranee and Kantee.

Hills west of Akranee.

To the west of Akranee fort, there occurs, along the southern verge of the range, a succession of steep craggy peaks, the form of which is widely different from the usual flat-topped or hog-backed ridges formed of the trap, and rather resembles in appearance hills of granitic or gneissic rocks. These peaks rise directly from the plains of Khandeish and tower some hundreds of feet above the general elevation of the range; to the north of them, broad terraces slope away to the northward towards Kantee. The beds of trap composing these terraces have a low dip to the north, which has evidently had but little to do with the peculiar shape assumed by the summits of the range; the latter must be due to subaërial denudation. By aneroid measurement, one peak, not the highest, but also not far short of the highest, was 3,200 feet above the plain of Khandeish, the latter being probably 600 or 700 feet above the sea, so that these hills are very little below 4,000 feet in height.

There is a fine view of this range from the neighbourhood of Kookurmoonda. To the westward the peaks cease, and the range

* It appears to be to the eastward looking from the plain to the south. These low dips on the larger hills are difficult to determine exactly without climbing the hills, which there was not time to do in every case.

sinks into the long flat-topped hills of Sakhbara, then trap closes in upon the Taptee from both sides, and the river enters the Rajpeepla jungles.

SECTION 8.—NERBUDDA VALLEY NORTH OF THE RIVER; FROM BURWAI TO DHURMPOOREE AND MANDOO.

Rocks occurring.

This area is entirely occupied by rocks belonging to the trappean series, and therefore requires no more than a passing notice. Near the river there is a great accumulation of alluvial deposits, and for two or three miles from the banks rocks are very rarely seen. In the river bed, however, trap frequently appears.

Trap of no great thickness.

There is every reason to believe that the trap in the valley is of no great thickness, and that lower formations exist at a moderate depth below the surface. The beds of trap are, as nearly as possible, horizontal, and some miles west of Burwai, shallow wells for irrigation pass through the trap into the cretaceous sandstones.

Granite in bed of Nerbudda opposite Mundlaisur.

Another instance of the proximity of the base of the traps may be seen in the occurrence of granite in the bed of the Nerbudda opposite Mundlaisur, a circumstance noted both by Major Stirling and by Captain Abbott, as previously mentioned. The masses of granite, many of them several feet in diameter, were considered by Major Stirling and Captain Abbott as pinnacles piercing the trap; they are, however, distinctly isolated and surrounded by trap, often permeated by veins of the latter, and more or less fused, so that on the edges a complete passage takes place from one rock into the other. This is especially well

seen near the largest block (Fig. 9). The trap around the various blocks

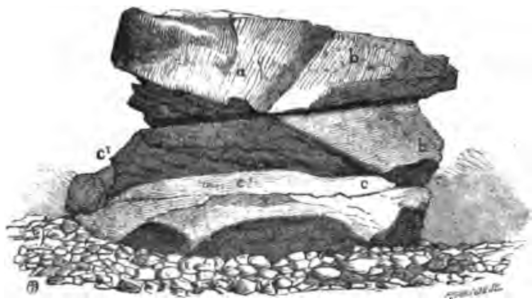


Fig. 9. On an island in Nerbudda river, opposite Mundlaisur: *a*, Granite: *b*, Granite passing into coarsely crystalline granite: *c*, Granite passing into trap: *c*[1], compact trap.

often contains large crystals of felspar precisely similar to those in the granite (which is chiefly pegmatite), and some spots are seen in which there is no granite, but still felspar crystals are diffused. Apparently the granite has in every case been more or less dissolved in the molten trap, and the felspar has again crystallized out upon the trap cooling, the quartz probably combining with the basic minerals of the trap. The smaller fragments of granite were evidently entirely dissolved, while larger masses were only fused and mixed with the trap on their edges.

It is by no means clear whether the trap occurs in a dyke or in a flow, the small island in which the granite masses occur being somewhat isolated. No distinct dyke can be made out, but nevertheless the blocks are not seen out of one general line. This might be caused in a flow, somewhat as lateral moraines are in a glacier, if the lava current passed by rises of metamorphic rock. The trap consists of felspar porphyry and differs from the distinctly bedded flows in the neighbourhood, so there is some probability of its being intrusive. Whether dyke or flow, however, is comparatively immaterial, the blocks of granite have evidently been brought up by the one or carried along by the other, and they are certainly not in situ.*

* For an instance of blocks of granite being included in a lava stream ejected from a volcano, see Daubeny on volcanoes, p. 337, and quoted by Lyell.

Columnar trap.

Much columnar trap is found in this neighbourhood. It appears to be partly in beds, partly in dykes like that already mentioned as occurring in the Dhar forest. Some good columns are seen between Mundlaisur and Muhesur, * and there are some very fine and remarkable columns radiating from a centre seen near Goojree, of which a drawing by Mr. Wynne is added. (Fig. 10).

Fig. 10. Trap in curved columnar masses : Dyke at Koteda, near Goojree.

Intertrappeans.

Around Goojree also intertrappean limestone, containing the usual fossils, is not of unfrequent occurrence. It may exist in other parts of the country; blocks containing *Melania quadrilineata* and other fossils were picked up near Dhurmpooree.

Scarp of Malwa plateau.

The scarp of the Malwa plateau north of Mundlaisur is straighter and more mural than anywhere else in this neighbourhood. In places it continues for miles as a huge cliff scarcely broken by a ravine. Passes are few; the Simrol Ghat

* These were noticed by Captain Dangerfield.

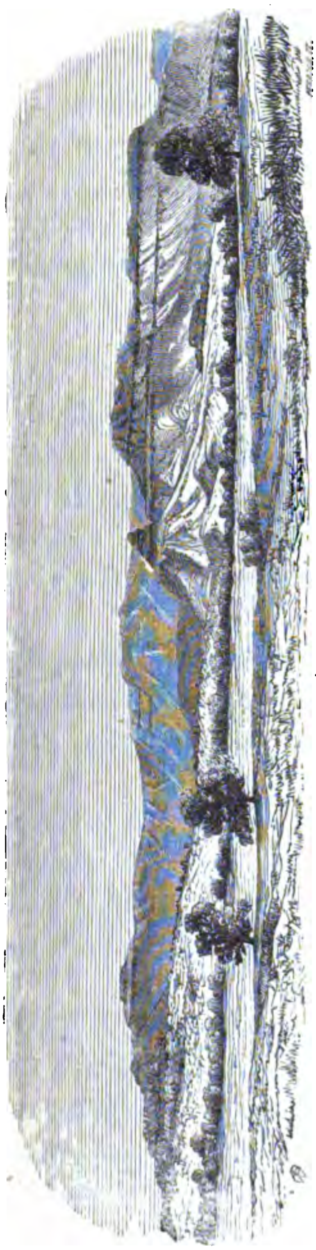


Fig. 11. Malwah Ghats, from near Goojree.

north of Burwai, the Jam Ghat north of Mundlaisur, and the Ghara Ghat by which the Bombay and Agra road ascends to the table land are the only important roads. The Jam Ghat is very interesting, as the road descends zigzaging down the face of the cliff and enables the characters of the rocks to be examined. The beds are extremely well marked and 14 distinct terraces* may be counted, as stated by Dangerfield. As the descent is about 1,500 feet, this would make the successive terraces a little more than 100 feet apart on an average. But in fact the higher terraces are much nearer together than the lower. The number of the lava flows which compose the scarp by no means necessarily corresponds to the number of terraces; it is probably much greater, since a terrace is only formed where two beds of different degrees of hardness come together; if two, three, or more beds, similar in mineral character, succeed each other, no distinction would be observed in their weathering. Two of the terraces above mentioned,

* This is the number given by Dangerfield, and which I counted myself, but other observers have thought the number different. Some are much less apparent than others; many are not seen in every spur of the hills.

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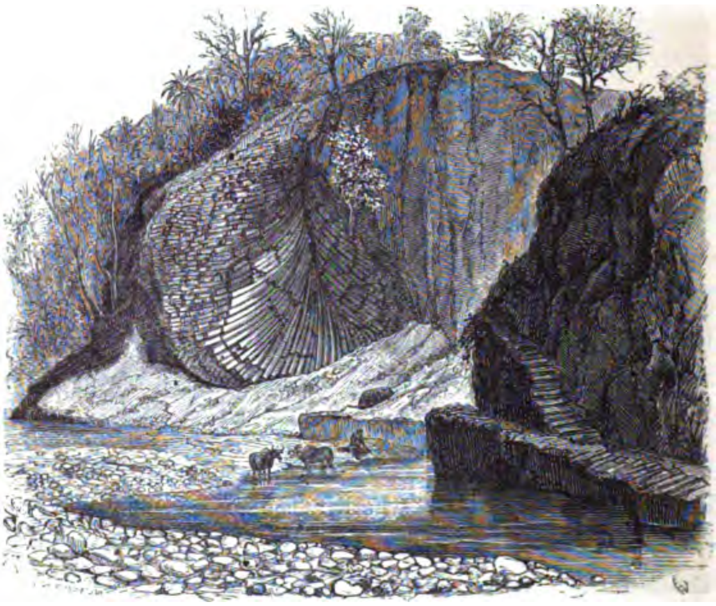

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* These were noticed by Captain Dangerfield.

Fig. 11. Malwah Ghats, from near Goojree.

north of Burwai, the Jam Ghat north of Mundlaisur, and the Ghara Ghat by which the Bombay and Agra road ascends to the table land are the only important roads. The Jam Ghat is very interesting, as the road descends zigzaging down the face of the cliff and enables the characters of the rocks to be examined. The beds are extremely well marked and 14 distinct terraces* may be counted, as stated by Dangerfield. As the descent is about 1,500 feet, this would make the successive terraces a little more than 100 feet apart on an average. But in fact the higher terraces are much nearer together than the lower. The number of the lava flows which compose the scarp by no means necessarily corresponds to the number of terraces; it is probably much greater, since a terrace is only formed where two beds of different degrees of hardness come together; if two, three, or more beds, similar in mineral character, succeed each other, no distinction would be observed in their weathering. Two of the terraces above mentioned,

* This is the number given by Dangerfield, and which I counted myself, but other observers have thought the number different. Some are much less apparent than others; many are not seen in every spur of the hills.

which are both near the top of the scarp, may be traced along it for a considerable distance (Fig. 11), and form a marked feature.

Ash beds.

Beds of volcanic ash may be seen in several places on the Jam Ghat; one especially well marked occurs about two-thirds of the distance down the hill.

Much ash (volcanic breccia) is also seen on the path leading to Mandoo from below the Ghat. It is generally weathered and exhibits its structure clearly.

SECTION 9.—NERBUDDA VALLEY NORTH OF THE RIVER; FROM NEAR MANDOO TO THE RIVER BAGHNEE, BEING THE COUNTRY AROUND BAGH.

Rocks.

Just west of Mandoo cretaceous limestones and sandstones begin to appear from beneath the trap in the deeper valleys, not far from the foot of the hills. In the neighbourhood of the Nerbudda, a southerly dip of all the rocks, which becomes more marked further west, brings in the trap.

The limestones and sandstones rest sometimes upon metamorphics, sometimes upon Bijawur beds. Occasionally the traps rest immediately upon the crystalline rocks without any sedimentary formation intervening. This is especially the case to the north.

Strike of foliation and cleavage.

A great change here takes places in the foliation strike of the gneiss and in the direction of cleavage and lamination of the Bijawurs. To the east in the Dhar forest and elsewhere, the general strike was east-north-east; near Bagh and to the west, it is nearly south-east.

Limestone fragment at Ookulda.

The most eastwardly inliers of sandstone seen were near the village of Dussai. A solitary fragment of limestone, evidently cretaceous, was picked up in the bed of the stream at Ookulda, but no more could be found, nor, despite some search, was any outcrop discovered, and as the limestone has been used throughout the country for building, this fragment might not have been derived

from the neighbourhood. At the same time there is a possibility that a very small exposure of the cretaceous beds further east than any marked on the map remains to be discovered.

Cretaceous beds near Dussai.

Three-fourths of a mile above Dussai, in a small stream tributary to the Maan, cretaceous beds come in below the traps. On the top of them are about 15 feet of purple and grey marls with limestone nodules. Beneath these is 'coralline limestone' apparently thinner than to the west. It contains near the base a nodular and slightly ferruginous band, in which *Hemiaster* is found in abundance, together with *Pecten 4-costatus* and a few other fossils, mostly bivalve shells, of which the *Ostreidæ* and *Inocerami* retain their shells, while other forms appear as casts. In the coralline limestone *Bryozoa* abound. Beneath these beds the top of a stratum of unfossiliferous nodular limestone is seen.

Much fossil silicified wood occurs, which may, possibly, be derived from the upper red marl with calcareous concretions, or from some sandstone, which, close by, at a village called Kirwan, overlies the red marl and forms the top of the Bagh beds. This bed is considerably higher in level than the others (all being horizontal or nearly so) which, in the Dussai and two other small parallel valleys, just appear above ground near the streams, while the sandstone caps the low intervening rises. It is only seen over a small space near Kirwan.

It is possible that this sandstone and the red marl represent some peculiar red beds presently to be described, which are found near Bulwarree.

Valley of the Maan.

West of these small inliers the cretaceous rocks next appear about four miles further, in the valley of the Maan river and its tributaries, where they occupy a considerable area, metamorphic rocks also being exposed. The Bagh beds appear to be more richly fossiliferous in this tract than in any other spot where

they have been examined, and the coralline limestone at the top is far better developed. Near Cheerakhan, the spot where distinct cretaceous fossils were first found by Captain (now Colonel) Keatinge in 1856, a very large proportion of the surface of the country consists of the coralline limestone. About half a mile north of the village, fine sections are seen in some glens. In these the uppermost 6 or 8 feet, sometimes more, is formed of this rock; below it there is argillaceous nodular limestone, and at the base of the formation a varying thickness of sandstone and conglomerate, occasionally, but rarely, less than four or five feet in thickness. Usually it is considerably more. The whole series here, however, does not exceed 60 feet in thickness, frequently it is less, in consequence of irregular denudation before it was covered by trap. So uneven is the surface on which the trap rests that at times it appears as if faulted against the cretaceous beds, or even as though underlying them, in consequence of its resting against old cliffs.

Cheerakhan.

The coralline limestone occasionally shews false bedding, and it appears to have been formed of broken fragments, in great part of *Bryozoa*. Numerous sections of it occur, for the country is covered with ancient quarries in it, slabs cut from which are said to have been largely used in building the palaces and mosques of Mandoo; a statement which is borne out by the character of the stone employed at that place.

Coralline limestone.

The nodular limestone, which underlies the upper 8 or 10 feet of coralline limestone, is frequently ferruginous and rubbly, and sometimes highly fossiliferous. From it the greater portion of the fossils as yet found in these beds has been obtained. The most abundant by far near Cheerakhan is an Echinoderm, *Hemiaster* near to *similis*. A small *Rhynconella* comes next in abundance, and then *Pecten* 4-*costatus*,

Nodular limestone.

Fossils.

Cardium (Hillanum?) an *Inoceramus,* 2 *Modiolæ,* a *Hemicardium* and other bivalves. These are mostly casts, as are also a few Gastropoda which accompany them. Besides the *Hemiaster,* some other *Echinodermata* are found, amongst them a *Cidaris.*

Section at Cheerakhan.

This fossiliferous bed, just north of Cheerakhan, was 8 or 10 feet thick, and rested upon 15 or 20 feet of unfossiliferous nodular limestone of a type much more extensively distributed than is the fossiliferous bed.

South of Cheerakhan.

Just south of Cheerakhan, the trap rests immediately upon sandstone, and here, as at Dussai, much fossil wood converted into a jaspery hornstone is associated with the latter. It is not clear that this sandstone is of cretaceous age. It might belong to the traps.

Rocks north of Cheerakhan.

In the upper Maan valley, north of Cheerakhan, there is no sandstone or limestone, and the traps rest directly upon metamorphic rocks. As will be seen, this is usually the case to the north.

Irregular junction of traps and cretaceous beds near Goorsul.

The surface is composed of metamorphics or cretaceous beds as far as Goorsul, on a tributary of the Maan river, 5 or 6 miles north-west of Cheerakhan. Here some good instances are seen of the irregular manner in which the traps rest upon the cretaceous beds. Close to Goorsul, metamorphic rocks occur in the stream; sandstone and limestone, the latter, as usual, above the former, form high terrace-like banks. But just north of the road from Boreghat to Goorsul, and upon the banks of the stream, trap rests directly upon metamorphics along the north bank of a small ravine, while on the south bank, within a few yards, is a hill of limestone. Again, in the flat ground of the valley close to Goorsul, a small hill of trap stands by itself, resting on the metamorphics, while the hills on each side of the valley are of sandstone and limestone,

and higher than the trap hill. All these are additional instances of the denudation of the cretaceous beds before the trap period. (Fig. 12).

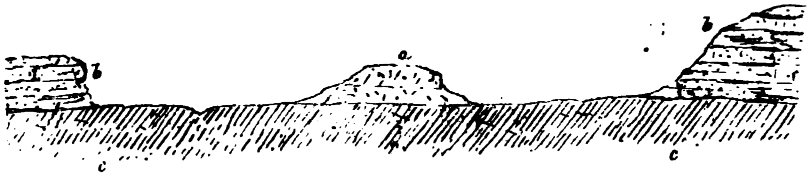

Fig. 12. Sketch section of traps, cretaceous and metamorphic beds near Goorsul: *a*, trap: *b*, cretaceous beds: *c*, metamorphics.

Rocks on Ooree river.

Between the cretaceous and metamorphic beds on the Maan river and those next exposed to the west on the tributaries of the Ooree stream, there is an interval of about 4 miles, occupied by trap as usual. About the Ooree river, there is still a considerable development of the coralline limestone, and fossils are still by no means scarce. The manner in which the rocks occur is precisely as to the east, the cretaceous beds forming an intervening stratum, of small thickness, between the traps and the metamorphics.

Red beds near Bulwaree.

South-east of Bulwaree between that village and Mohunpoor there is a high level tract of Sálee (*Boswellia thurifera*) forest, formed of a peculiar red rock, calcareous, but having frequently a brecciated appearance, being traversed by a net-work of fine quartz veins. It often consists of laminæ of red and white limestone. It has somewhat the appearance, near Mohunpoor, of passing into the ordinary Bagh beds, but this is far from clearly seen. In another place, it appears to rest upon trap, and to pass into a crystalline trappean looking rock, but upon this observation also no great reliance can be placed. It is by no means clear whether this bed should be classed with the Bagh beds or with the traps. It may be

of the former, but altered by the action of the latter. It is also possible that it belongs to the Bijawurs and represents some beds of that series occurring near Jobut, to be hereafter described. But against this it may fairly be argued that no other Bijawur beds are seen in the immediate neighbourhood, while metamorphic rocks occur at both Bulwaree and Mohunpoor, and that it is less hardened and altered than any other Bijawur rocks in the country.*

Cretaceous beds near Joona Pani.

On the Ooree river, near Joona Pani and Koja Kooa, the sandstones of the cretaceous formation, occasionally replaced by coarse conglomerates, thicken considerably, and cover a comparatively large area, forming flat topped hills with only an occasional cap of trap. The conglomerate contains pebbles of quartz and gneissose rocks, which frequently remain scattered over the surface when the matrix is decomposed and removed. A similar conglomerate is common further west.

Dips.

The sandstones here have in general a very low southern dip, which is also seen near Bagh. It does not exceed 1°, if indeed it be so much; but very considerable disturbance and high dips are met with south of Koja Kooa, which is an unusual occurrence amongst the Bagh beds in this part of the country. Near Anjuntal they dip for some distance to the north at an angle of 15°.

Bijawurs near Koja Kooa.

Between Koja Kooa and Anjuntal Bijawurs are exposed in the Ooree. The typical laminated siliceous limestones, with clay slates and breccia, occur striking north-west to south-east, and vertical. In one place the original bedding was seen crossing the cleavage at right angles. In the limestones there is much apparent contortion. The boundary between these beds and the metamorphics is probably a continuation of the fault boundary seen north of Bagh.

* This tract was not closely examined, and no opportunity was afforded of returning to it after examining the Jobut beds.

General distribution of beds in Ooree valley, near Koja Koos.

The valley of the Ooree river about Koja Kooa is, for many miles, occupied by metamorphic rocks, which extend also far up the side valleys. Between the several depressions in which the cretaceous beds and metamorphic rocks are exposed, great flats of trap extend : these are, however, mere caps, cut through by every little ravine. The surface of the metamorphic rocks upon which the cretaceous beds were originally deposited is also very uneven. From all these circumstances there results extreme irregularity in the outline of the various formations. This has not been shown in detail on the map, and indeed it could only have been correctly delineated upon a far more detailed and accurate representation of the topography of the country than that available for the purpose, nor could it be represented at all upon a map on so small a scale.

Section near Tanda.

Along the north of the metamorphic area in the Ooree valley, and also further west, there is no such continuous representation of the cretaceous beds as is seen to the south; indeed their occurrence is rare. This appears to be partly due to their having originally been very thin or wanting in places, partly to subsequent denudation. Thus at one spot about a mile west from Tanda, and just south of the little Bheel village of Bukki, on one side of a stream, sandstone, and limestone capped by trap, rest upon the metamor-

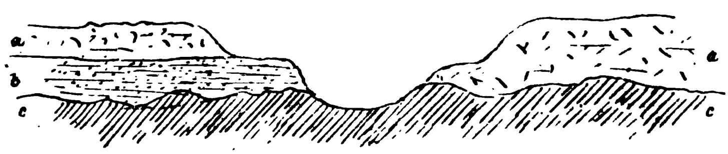

Fig. 13. Sketch section of trap, (*a*,) resting on irregular surface of cretaceous beds, (*b*,) and gneiss, (*c*,) west of Tanda.

phics, while in the stream-bed trap is seen, and on the opposite bank it rests directly upon the gneiss (Fig. 13). The sandstone is coarse, often

conglomeritic, nodular and compact, resembling that seen near Bagh, and containing greenish chert. Limestone occurs near the base. Near the top of the sandstone, which is about 50 feet thick, other bands of limestone of a different character occur, containing *Bryozoa* and other fossils. These thin bands represent the coralline limestone, so highly developed a few miles to the east.

Another small patch of cretaceous rocks, 200 or 300 yards in length, was met with south-west of Dairee, and doubtless many similar small remnants occur scattered over the country. But along the greater part of this boundary, the trap rests immediately upon the crystalline rocks.

Termination of Malwa scarp.

About Tanda the Malwa scarp commences to lose its persistent character. The metamorphic rocks run further and further to the north up every successive valley to the westward.

Between Tanda and Bagh, very little of the cretaceous beds is seen until the neighbourhood of the latter place, when they come in in considerable force. Hence to the westward they occupy a large area.

Cretaceous beds near Bagh.

The boundaries are irregular as usual. Although the cretaceous beds increase in thickness to the south, they are still, over the greater portion of the area, but a thin band, cut through in the deeper valleys, while patches of trap rest everywhere irregularly upon them.

Conglomerates prevail near Bagh, especially to the north of the town, and the pebbles from them are spread over the country. On some hills north of Agur, the sole beds seen between the trap and the Bijawurs are these conglomerates, which are about 60 to 80 feet thick. The coralline limestone disappears as a distinct bed, and although a limestone with fossils, occasionally including *Bryozoa*, is met with west of Bagh, it is no longer such a mass of comminuted corallines as to the east. The very low southerly dip which is prevalent in the cretaceous beds may have originally existed, and may mark increasing depth of water to the southward, where the beds are thicker. But this is very doubtful.

Section in Baghnee river.

The section seen in the Baghnee river, south of Bagh, presents but little interest, though the stream traverses cretaceous beds for a distance of 3 or 4 miles. Almost the only rock seen is sandstone. The dip is so low that it appears to coincide with that of the bed of the stream, and the same or nearly the same section is exposed throughout. Opposite the town of Bagh, this section consists of—

Section of cretaceous rocks opposite Bagh.

Nodular flesh colored limestone, apparently unfossiliferous, or only containing obscure casts of shells ... 15 to 20 feet.

Fine white and purple sandstones or coarse gritty beds. The base consists of conglomerate, shaley purplish sandstone, and coarse falsebedded gritty sandstone. Some of the shaley beds are calcareous, and contain a few imperfect bivalves, ill preserved ... 80 to 100 feet.

In the sandstones, bands of small pebbles of jasper, quartz, and quartzite occur, the latter apparently derived from the Vindhyans.

Caves of Bagh.

In these beds are the caves of Bagh, remarkable as being almost the only Buddhist caves in India, except those of Bhobaneshwar in Cuttack, which are in sandstone. All the other caves of Western India are in trap. The rocks at the caves are fine purplish and white sandstone and silty sand, falsebedded and strongly rippled on the surface of the beds.*

South boundary of cretaceous beds near Bhilahee.

Just north of the village of Bhilahee, the cretaceous rocks terminate abruptly. Their uppermost bed is here a peculiar limestone, having a brecciated appearance, which rests upon coarse rather vitreous sandstone weathering into knobs. The apparent brecciation of the limestone is perhaps

* I have before shown the mistake committed by Dr. Martin Duncan in Quarterly Journal, Geological Society, Vol. XXI, p. 350, in supposing that Captain Keatinge's fossils were derived from this spot.

due to silicious infiltration, much of which is seen further west in the uppermost beds of the cretaceous series.

Bijawurs of Bagh.

The town of Bagh itself rests upon Bijawurs, a peculiar triangular patch of which is let in by two faults, one striking about north-20°-west, the other nearly north-west, the latter coinciding with the foliation of the gneiss and the cleavage lamination of the Bijawurs. These two faults meet, and the Bijawurs are cut off about 7 miles north-north-west of Bagh, near the villages of Borekooa and Chundawud, while to the south they disappear beneath the cretaceous sandstone and trap. As is usual in areas the surface of which is composed of Bijawur rocks, (unless thick deposits of alluvial soil supervene,) this tract is a jungle, the soil worthless for agriculture, and the surface hilly and irregular.

Many of the kinds of rock which occur in the Bijawurs are well seen close to the town of Bagh. There is not a good section in the bed of the Baghnee which, indeed, only traverses these rocks for a short distance, but the hills around the town are rocky, and the jungle in general not sufficiently high to conceal the rocks. The hill on which the fort stands is partly composed of red brecciated quartzite with iron ore, the latter chiefly brown hematite. At the south end of the hill, close to the town, and on the east side, the bedding of these rocks is distinctly seen. They dip at 70° to east-30°-north and rest on limestone. To the west they turn over and dip the reverse way, so that the hill is the axis of a small anticlinal. The bedding cannot, however, be traced to any distance in this direction, indeed it is only conspicuous in the jaspery beds, and a short distance from the hill it is completely obscured by cleavage; while the rocks are a confused mixture of slates, limestone, breccia and trap as far as the boundary fault, which is not distant. On the east, however, the strike of the bedding appears closely to coincide for some distance with that of the cleavage foliation, and the following beds come in upon the breccia.

Rocks east of the Fort hill.

In the valley east of the Fort hill, a greenstone-like trappean rock is seen. This rock, which is frequently met with in the Bijawurs about Bagh, is generally highly cleaved, though the cleavage surfaces are rough. It sometimes much resembles the more obscurely crystalline forms of hornblend rock which occur in the metamorphics. This may be an interstratified trap, contemporaneous with the Bijawurs.

Next comes some white vein quartz, which possibly marks a fault or line of fracture. The hill east of the valley is composed of black and purple clay slates, interstratified with occasional sandy beds, and with bands of a rock resembling a conglomerate of quartz pebbles elongated in the direction of the strike of the cleavage, but the apparent beds are, really, nodular masses of quartz elongated in the cleavage strike, which are evidently the result of incipient lamination. The cleavage here strikes north-30°-west vertical. Beyond the hill again there is another band of the cleaved greenstone.

A few hundred yards further east is the road from Bagh to Tanda, *viâ* Agur. Slates are well exposed in some small sections east of the road, and bedding is here distinctly seen crossing the cleavage. The latter is not quite steady, it here strikes about south-25°-east. Bedding distinguished by bands of different colours is seen dipping south-east, varying to south, at an angle of about 45°. It is somewhat contorted. Slates for roofing purposes might be obtained here, though not of large size.

North-east of the slates is a bed of breccia, with jasper of a bright red colour. This rock is highly ferruginous, and much of it resembles that quarried near Burwai for iron ore.

The next band is a talcose quartzite, extremely foliated and metamorphosed, with large irregular masses of quartz in the foliation, giving the weathered surface the appearance of pegmatite or of granitoid

gneiss. A more thoroughly metamorphic rock it would be difficult to conceive.*

This formation is immediately succeeded by laminated siliceous limestone, to that follows massive quartzite, upon which comes limestone again with some iron ore at the base. In the limestone, close to the road, bedding is seen, dipping at a low angle to about north-20°-east, the cleavage lamination striking here west-30°-north, so that the two nearly coincide in direction, although the dip of the cleavage is higher. Following the limestone band to the eastward, it is found to strike gradually away from the direction of the cleavage.

The above gives a fair idea of the general succession of beds seen in the Bijawur series near Bagh. It is highly improbable that it should be a simple ascending series; almost without doubt it is complicated by faults and contortion. Its peculiar interest, however, lies in the illustration which it affords of the parallelism of the cleavage and lamination, and of the different strike of the bedding; for the lamination so frequently has the appearance of bedding that it is necessary to be very careful amongst these rocks in distinguishing between the two. As a rule, no bedding is seen except in the breccias and quartzites.

Bijawurs near Agur.

The above, however, do not comprise all kinds of rock seen in this country. In some places, near Agur, perfectly unaltered sandstone is met with. Near the boundary fault, on the road between Agur and Nahwel, on the other hand, some limestone contains talcose layers, and plumose crystallization, probably also of talc, in the cleavage planes. This is at about 200 or 300 yards distance from the boundary, the breccia and limestone nearest to the metamorphics, and only separated from them by the boundary fault, being unaltered.

* It has occasionally occurred to me that the more highly metamorphosed condition of particular beds, especially when quartzose, may have been due to the more easy permeability of the original sedimentary rock composing them by heated vapours, or mineral water.

North-east boundary fault of Bijawurs near Ekra.

The fault running north-west and south-east is in places, as near Ekra, marked by a mass of vein quartz. Its direction is, in general, nearly parallel to the cleavage of the Bijawurs and the foliation of the gneiss, but not always exactly so, the cleavage near the fault being occasionally bent and twisted, showing that it is of anterior date to the faulting.

South-west boundary fault.

The other fault bounding the Bijawurs to the south-west is well seen in the Baghnee, south of the town of Bagh. The Bijawur series is there represented by the typical laminated limestone, which abuts against greenstone belonging to the metamorphics, but only distinguished from similar beds in the Bijawurs by the granite veins and laminæ of quartz which it contains. Just east of it gneiss with granite veins comes in.

This fault disappears to the south beneath the cretaceous rocks; to the north it runs for several miles up the valley of the Baghnee in a straight line, striking about north-30°-west, cutting across the foliation of the gneiss and the cleavage of the Bijawurs. The fault itself is a mere crack, but it is easily traced amongst the rocky hills just west of Bagh, as different beds of each of the groups in succession are brought against beds of the other and cut off. To the north, near Borekooa, some of the metamorphics are so slaty that it is difficult to distinguish them from the clay slates of the Bijawurs, and in a stream which runs into the Baghnee a little south-east of the village of Borekooa, and which exposes a fine section of both groups, it is so difficult to ascertain the exact boundary that the two series appear to pass into each other.

Iron ore of Bagh.

The iron ore which forms the matrix of breccia close to the town of Bagh was formerly worked largely. The workings have now been abandoned for many years, and the manufacture of iron is extinct in the country, owing, doubtless, to the destruction of the jungles.

There is but one more place to the westward where Bijawurs are met with in the Nerbudda valley: this is near Jobut; the description will be found below.

SECTION 10.—NERBUDDA VALLEY NORTH OF THE RIVER, FROM THE BAGHNEE RIVER TO CHOTA OODIPOOR.

General distribution of rocks.

From Bagh to Chota Oodipoor the surface is principally formed of metamorphic rocks occupying the area between the trap plateau of Malwa (which ends by sinking into the plain near Kunas and Bhabra) and the great trappean area to the south. The metamorphic country is an extensive undulating plain with only occasional hills, more or less isolated, of granitoid forms of the gneiss. The trap country to the south is very hilly, and it appears singular that the river should traverse it in preference to the broad plain of the metamorphics. The traps come in south of Allee and Panwud with a sharp southerly dip, which fully accounts for the entire disappearance of the older formations beneath them.

The sandstones and limestones of the cretaceous rocks intervene generally between the traps and the metamorphics, and uniformly increase in thickness from north to south. To the north, in the same way as east of Bagh, they are frequently deficient, and never exceed 60 to 80 feet in thickness; to the south they frequently attain 500 feet or even more. The thickness of the upper fossiliferous and calcareous band increases to the south, as well as that of the underlying unfossiliferous sandstone. The coralline limestone is wanting.

Tract of cretaceous rocks west of the Baghnee.

West of the Baghnee river there is a considerable tract of country, about 12 miles from east to west and 15 from north to south, almost entirely composed of sandstone: it is one of the largest continuous areas occupied by the cretaceous rocks. It is occasionally cut through by streams, and the metamorphics are exposed beneath, as to the south of Kunwara, and outliers of trap are scattered over it.

The outline of this patch of sandstone is irregular. It is separated from the trap area to the north by a narrow belt of metamorphics; metamorphics also lap round it to the east.

The rock is principally sandstone, limestone being of less frequent occurrence at the surface. Fossils are scarce. A few large oysters with long projecting hinges were found in two places. The beds are horizontal or nearly horizontal throughout.

In describing the country to the west it will be most convenient first to treat of the southern* and subsequently of the northern portion, commencing in each case from the east.

Its western edge.

The west edge of the patch of sandstone just described forms a low scarp rising from the metamorphic country. This runs down to the Huthnee river not far from the village of Chiklee. Below this the Huthnee and its tributary the Sookee cut deeply through the sandstone, the banks being frequently formed of high cliffs of that rock. In the Huthnee, west of Chiklee, much limestone occurs, perhaps in part representing the coralline limestone; it contains small layers made up of organic remains, amongst which *Cidaris* spines are abundant. The limestone beds here are very massive, some of them 20 feet thick. Red sandstones also occur. Much of the limestone is dove-coloured.

Sections in Huthnee river.

Unconformity of trap on sandstone.

The trap in this neighbourhood rests upon a very uneven surface of the sandstone, the latter rising in places above the level of the former. This is especially well seen east of Morasa.

Rocks in the Sookee river and near Dhi.

In the Sookee, west of Morasa, the stream cuts its way between vertical cliffs, 250 feet high, of trap, somewhat columnar in structure. Thick limestone comes in below the trap, and is well seen on the road to Dhi. It is cherty and in places conglomeritic. Reddish calcareous

* The whole description of this portion is from Mr. Wynne's notes.

sandstone rich in fossils, including corals, oysters and other bivalves, *Gastropoda* and occasionally *Ammonites*, occurs below the limestone; but owing to the hardness of the rock and its mode of weathering none of these fossils can be got out.

Section in Huthnee below junction with Sookee.

Below the junction of the Sookee with the Huthnee, the latter stream flows chiefly between cliffs of sandstone for some miles; the limestone, which is higher in the series, not continuing to appear down the stream. The sandstones vary; at first they are fine in texture, red and yellow, obliquely laminated at the top, and flaggy, interstratified with purple sandy layers. These layers are occasionally shaly, and the alternations with the sandstone very thin. Some of the sandstone beds are conglomeritic.

Near Dilwanee.

Further down the stream, near Dilwanee, white sandstone predominates. It rolls about, being in general nearly horizontal. The rocks here dip to the south, and the higher beds, including the limestones, again appear in the stream; near Ravar strong slabs of calcareous breccia, containing bone fragments, are seen. This bed is perhaps the same as one containing sharks' teeth, which is found farther west in the Rajpeepla hills.

Near Hutwee.

Near Hutwee there is a fine cliff at the side of the river. The upper 35 feet are of white sandstone, and thin shaley and flaggy white and greenish beds; these are succeeded by 30 feet of dark green or black amygdaloidal basaltic trap, columnar in places, beneath which sandstone occurs again. The trap appears to conform distinctly to the lines of bedding, although some slight irregularity occurs along the junction. The sandstone below the trap is very little, if at all, altered.* At the north end of the section are some small faults,

Apparent interstratification of trap.

* This trap is doubtless a horizontal dyke, like some other cases to be noticed. Interstratification of traps has not been observed in the cretaceous beds.

and finally the trap is cut off by a larger throw which brings in limestone against it.

Huthnee river below Hutwee.

One inlier of sandstone is cut through in the Huthnee below Hutwee; thence to the Nerbudda the stream makes its way through trap rocks, which have an unusual amount of inclination. At one place a dip of 25° to the south is seen, and 15° continues for a little distance, but the average dip is about 5°. Along the Nerbudda for many miles east and west of the mouth of the Huthnee the same dip exists.

Inlier of cretaceous beds near Dhurmrai.

East of the Huthnee, between that river and the Baghnee, in the neighbourhood of the Nerbudda, several cretaceous inliers occur, surrounded by trap rocks (see map). Near Dhurmrai, in one of these, fine glens are cut by a stream exposing a great thickness of sandstones and shaly beds. These inliers are composed of rocks similar to those entering into the composition of the Bagh beds elsewhere in the surrounding country.

West of the Huthnee.

Sandstone near Nanpoor.

Passing west of the Huthnee, the boundaries of the trap, cretaceous beds, and metamorphics are, for some distance, very irregular. South-west of Nanpoor a tract of sandstone projects for 3 or 4 miles into the gneiss area. It consists of cherty limestone, sometimes breaking with a crystalline glistening fracture above, white sandstones and red argillaceous rock resting on white conglomerate below. To the south of it is a great bay of the metamorphics. In this, close to Soolgaon, is a craggy hill of a peculiar white rock, resembling that which is found near Hurrungaon, east of the Dhar forest.

From Walpoor to Allee the boundary of the trap is so straight that it is almost certainly a fault striking west-25°-north. The sandstone disappears about half-way and the traps abut against the metamorphics.

Allee.

Sandstones come in again, however, after a break of about 3 miles, at the hill on which stands the fort of Allee. The western sides of this hill are very precipitous. A thickness of about 150 to 200 feet of sandstone is seen; upon this rests conglomerate, capped by limestone with flinty or cherty masses. A few corals and corallines occur. Some specimens of *Hemiaster* and a fragment of an *Ammonite* were also found.

Cretaceous rocks west of Allee.

West of Allee the belt of sandstone runs nearly east and west, and is very narrow in general, expanding to a breadth of about 3 miles in only one spot near Mainee. South of this at least 2 bands of limestone occur in the cretaceous beds. They contain oysters and other fossils. The remainder of this tract presents no features of importance. The metamorphics about Rajpoor are mostly granitoid; metamorphic limestone occasionally occurring. Near Phoolmal, however, they are highly schistose.

Metamorphics near Rajpoor.

Mutwar hills.

The range of the Mutwar hills which rise from the north bank of the Nerbudda west of the Huthnee, and lie south of Allee and Phoolmal, probably contain a few inliers of cretaceous rocks corresponding to those of Dhi and Dhurmrai to the east, and others near Kawat, &c., to the west. As, however, it had been ascertained that the mass of the hills consists of trap, and but a small portion of the season remained for the examination of a large area to the north-west, this tract was not surveyed in detail.

Rocks along northern part of section.

The rocks along the northern portion of this section of country are equally interesting with those along the south. Besides trap, cretaceous beds and metamorphics, they comprise a small tract of Bijawurs of somewhat peculiar character situated between the towns of Jobut and Kunas.

The metamorphics between Bagh and Jobut are much concealed by trap and cretaceous beds. Where exposed they are not, in general, highly crystalline or granitoid. The strike of the foliation is steady, almost constantly within 20° of north-west to south-east.

Metamorphics between Bagh and Jobut.

A good section of these rocks is seen in the upper Baghnee river, from a little south of Borree, where the stream leaves the trap, to Bagh, where it enters the Bijawurs, a distance of 13 or 14 miles. Near Choria, where the metamorphics first crop out from beneath the traps, the former consist of contorted chloritic quartzose schist, vertical or nearly so, and striking about north-west to south-east. The rock is slaty in appearance, and, in places, brecciated. It contains bands of grey quartzite with partings of chlorite. This passes into talcose slate, associated with granular quartzite, containing chlorite interspersed. Farther on the same rock becomes more gneissoid, containing felspar and, in places, mica. The next bed seen is greenstone, composed of hornblend and felspar, at first without any foliation structure, but passing gradually into a more schistose rock containing quartz veins. All of these beds have a greenish colour, due to interspersed chlorite.

Section in Upper Baghnee.

The next bed that is seen is close to the village of Kurchut. It is but indistinctly crystalline, the minerals contained being very obscurely seen, but it appears to consist of hornblend and felspar, with carbonate of lime. It is so soft that it may be scratched with a knife in parts. It is greenish in colour, and distinctly foliated, with quartzose layers in the line of strike, and, in places, fine reticulated quartz veins. This rock occupies the bed of the stream for at least a mile. It then passes gradually into a micaceous hornblend schist associated with true gneiss, and all the beds begin to be far more crystalline than near Choria. Passing further down the stream near Chundawud, granite veins are

met with, ramifying through the greenstone-like hornblendic rock, but preserving a general tendency to parallelism with the foliation strike, as usual. These veins consist principally of quartz with flakes of mica.

From this to Bagh similar highly crystalline rocks prevail, granite veins being frequent. Much greenstone occurs, sometimes devoid of foliation, at others laminated and schistose.

The section thus detailed is principally interesting as illustrating the gradual passage from a less to a more highly crystalline form of the metamorphic rocks. There is, however, throughout this tract no approach to the excessively granitoid development which takes place further west.

Cretaceous beds west of Borree.

Just south of Borree cretaceous beds appear to be wanting. To the west of that place they are thin when they occur, never appearing to exceed 30 or 40 feet in thickness. Sections of this kind (Fig. 14) occur, shewing local denudation of the cretaceous beds.

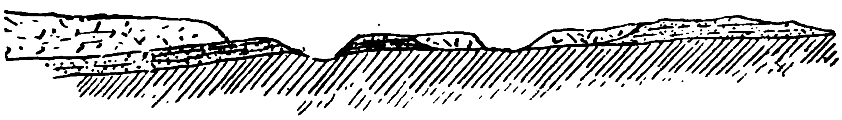

Fig. 14. Sketch section of unconformable junction between trap and cretaceous beds, near Sialee, west of Borree.

North-west of Borree the traps are not horizontal; they have a low dip of about 3° to the north-west.

Conglomerate near Mohri.

On the road from Borree to Kunas a stream is crossed just west of the village of Mohri, and, at the ford, there is a small patch of conglomerate, composed of large pebbles of gneiss, granite, &c., 8 or 10 inches in diameter, in a sandstone

matrix. This rock can only be traced for a few yards in the stream; it is evidently deposited in a hollow in the metamorphic rocks, which form the banks. It is quite unlike any of the cretaceous beds, and has a much older appearance, yet as no other sedimentary rocks appear in the neighbourhood, it is difficult to conceive to what other series it can belong. It is compact and resembles some of the Talchir beds. No fossils could be found in it.

Cretaceous beds near Unthee.

A little further west, about Unthee, there is a small exposure of sandstone, but it is very thin. South-east of Unthee, where these beds die out (near Kunas trap rests directly on Bijawurs), they consist of a very calcareous conglomerate, abounding in irregular angular masses of quartz, and so strongly resembling some of the quartzo-calcareous rocks of the Bijawurs that they can only be distinguished by the pebbles of red jasper and other minerals derived from those beds which they contain.

Bijawurs of Jobut and Kunas.

Immediately south of this is the tract of Bijawur rocks already referred to as existing between Jobut and Kunas, and which may be described here. It is of rather irregular form, approaching a triangle with rounded angles. The boundaries are not so distinct as are those of the Bagh patch, but here also they appear to be in great measure faults. The map upon which the lines are laid down is not very accurate in detail, and the boundaries of the formation are possibly straighter in reality than they are represented, at the same time some of the curves in the junction near Jobut have much the appearance of belonging to a natural boundary.

Red jaspideous rock.

The chief characteristic of this tract of Bijawurs is the prevalence of red jaspideous rock, less brecciated than it generally is. It is a ferruginous jasper with fine irregular veins of white silica, more or less amorphous, and occasionally resembling Chalcedony or hornstone; it covers the surface nearly from Kunas

to Jobut, the soil resting upon it being, as usual, thin and barren, and the ground uncultivated. The resemblance of this rock to that occurring near Bulwarree has been already referred to.

It is of course possible that this singular jaspideous rock, which is evidently nearly horizontal, may be newer than the Bijawurs, and rest upon them. But the appearances were not in favor of such a supposition. With the sole exception of this rock, the Bijawurs of this patch have a more crystalline and altered appearance than those near Bagh, and a peculiar form of granite rock is in places associated with them.

Surface of red beds irregular.

Just east of Kunas, at the north-west corner of this small patch, the jaspideous red beds crop out from under the trap. Their surface is irregular and the trap rests upon them unevenly, sandstone of the cretaceous rocks only intervening where hollows exist in the surface of the breccias, so that there appears little doubt but that the sandstones were only deposited in places, and it is probable that large portions of the Bijawur surface were not overflowed by the cretaceous sea.

Bijawurs east of Kunas.

Passing eastwards from Kunas, south of Unthee, the boundary of the raised tract of jungle formed by the jaspideous breccia trends away to the south-east. Metamorphic rocks come in, but between them and the jasper, and apparently lower than the latter, are some ill-cleaved black and grey slates, the cleavage foliation of which dips to the south-west. Immense masses of crystalline white quartz occur in them, especially at the boundary with the metamorphics, some appearing also in the beds of the latter. This prevalence of vein quartz, which was also observed in places on the boundary of the Bagh patch of Bijawurs, is strong evidence of faulting. The lamination of the metamorphic rocks, as at Bagh, is parallel to the cleavage foliation of the slates.

Similarity in composition of Bijawurs and metamorphics.

There is also a great similarity in the composition of the beds appearing in the two series, despite the more highly crystalline condition of the metamorphics. A remarkable instance is seen just west of Kotra amongst the latter. A limestone occurs with quartzose interfoliation, and in consequence of the manner in which the latter weathers out, the exposed surface of the rock presents the most striking similarity to that of the peculiar quartzose Bijawur limestone. In this metamorphic rock, the same irregularly shaped masses of quartz and even the peculiar brecciated appearances may be traced which were described in treating of the Bijawurs of the Dhar forest. On fracture the metamorphic limestone is seen to be much more highly crystalline, and to contain layers of mica and other minerals, but it differs in no other respect from the Bijawur rock.

Bijawurs north-west of Saimulda.

The village of Saimulda, like most of the Bheel villages in this country, is scattered over a considerable area. It stands upon metamorphic rocks. North-west of it, within the Bijawurs, are various kinds of talcose and schistose slate of different colours and quartzite, the latter containing pseudomorphous cavities, apparently after crystals of magnetic iron. In one spot a vein of coarsely crystallized ternary granite, about 6 or 8 feet broad, is distinctly intercalated in the cleavage strike. It differs greatly in appearance from the granites generally found in the metamorphics. Much pure white quartz is associated with it. The purple schistose slates in contact with the granite are not more crystalline than usual. This is the only instance in which granite has been observed in the Nerbudda valley distinctly intercalated in the Bijawurs, but another form of granitic rocks prevails extensively a few miles further to the south-west near Jobut, and will be mentioned presently. The locality of this granitic vein was not far from the boundary of the metamorphics.

Granite in Bijawurs.

Apparent passage of Bijawurs into metamorphics.

Close to a village called Andharee, west of Saimulda, the slates of the Bijawurs appear to pass into gneiss and hornblend schist. The slates along their strike become distinctly more and more crystalline, as the metamorphics are approached, the passage from clay slate to schistose slate being excellently seen. Still a fault may separate the two rocks, for a similar supposed case of passage on the edge of the Bagh patch of Bijawurs proved, on further and closer examination, to be merely apparent. Near Saimulda an altered conglomerate of quartz pebbles was found in the gneiss, furnishing ample proof, if necessary, of its originally sedimentary origin.

Conglomerate in gneiss.

Scarp formed by red jaspideous beds.

Upon the slaty and schistose rocks just described, the ferruginous jasper appears to rest almost horizontally. The area composed of it is bordered by a low scarp, which runs south-east from near Unthee to close to Andharee, and then turns sharply to the south-south-west. This scarp is here composed of the red ferruginous beds above, and of calcareous schists, rather more crystalline than usual, below. At the base, south of Andharee, the metamorphics come in. It is difficult to decide whether this boundary is a fault or not. Its straightness and the circumstance that south of Andharee the ferruginous beds are brought against the metamorphics, whilst to the north, slates and other rocks intervene, are in favour of faulting, but the former does not necessarily prove a disturbed boundary, and the apparent disappearance of the lower Bijawurs might be due to their conversion into crystalline rocks.

Calcareous quartzite near Jobut.

Near Jobut much hard calcareo-siliceous rock occurs, micaceous and dark grey in colour. It is different from any beds usually met with in the Bijawurs. Wherever lamination can be seen, it is in the usual north-west and south-east direction. About a mile north of Jobut, on the road to Kunas, there is a great quantity of a granitoid rock within the Bijawur area. It

abounds in a green mineral, resembling decomposed epidote, hornblend in masses, bronzite and the picrosmine variety of serpentine. Very possibly all the other minerals mentioned are only results of the alteration of hornblend and epidote.

Granitoid rock.

About 3 miles north-west of Jobut, and nearly due south of Kunas, near Jeri, the red beds are distinctly brought against the metamorphics by a fault running north-west to south-east. The Bijawurs here terminate, as usual, in a low scarp, on the top of which the red jaspery beds are met with, distinctly nearly horizontal, their bedding being well seen in a small glen, cut by a stream which issues close to Jeri village. The uppermost bed, a red jaspery rock with white veins, is alone seen up the glen, the bottom of which is concealed by a deposit of carbonate of lime. Below the red bed, on the scarp bounding the Bijawurs, are calcareo-siliceous beds, sandy in appearance, abounding in strings and nodular lumps of quartz, and having a remarkable resemblance to some of the calcareous cretaceous rocks. They are similar to the beds already mentioned near Jobut. These strata, instead of being horizontal, like the red beds above, are more or less contorted, and, especially towards the bottom of the spur, they are nearly vertical, their strike being parallel to that of the metamorphics close by.

Fault boundary near Jeri.

Red beds, &c., near Jeri.

The sudden apparent change in the strike from the horizontal red rock above to the vertical calcareous rock below might be accounted for by any one of three ways. 1. The rocks may be unconformable; but if they were, the separation would probably be more marked and distinct, and it is improbable that over a considerable area, one form of rock alone should underlie the jasper, as appears to be the case, the same calcareous sandy beds having already been noted beneath the red beds north-east of Jobut, 3 or 4 miles from Jeri. 2. The beds may be bent over near the boundary fault. This is more probable, but as the downthrow is to the north,

Appearance of unconformity between red beds and calcareous rock beneath.

the Bijawurs ought to be turned up against the metamorphics, whereas the appearance presented is that of their being turned down, and it is strange that no tendency to any curve should be seen in the red beds, while all the underlying rocks seen are either much curved or nearly vertical. 3. There only remains the supposition that the bedding has been preserved in the red beds, while in the calcareous and sandy rocks it has been obliterated and superseded by cleavage-foliation. But the pressure necessary to cause cleavage so strongly marked must have produced some effect upon the jaspery red beds. It seems probable that this effect is the brecciation, which, although less marked in the Jobut area than elsewhere, is still more or less universal. In some cases it is as strongly marked as ever; one fragment was picked up of a breccia similar to the remarkable form previously described as occurring north-west of Chandgurh in the Dhar forest, in which stratified quartzite appeared, as it were, permeated by strings of red jasper.

Bijawurs of Jobut probably nearly horizontal.

The conclusion which appears most probable is, that the Bijawur beds of the Jobut patch are horizontal or rolling at low angles, although they are more crystalline than usual, and although granitoid rock of two distinct kinds is associated with them. It is probable that all the high dips noticed in the slates and schistose beds are due to cleavage, and that the original bedding is preserved in the jaspery red beds alone, the hardness of which, and their resistance to denudation, have preserved a raised tract, over which they form the surface rock, above the level of the surrounding country. It is possible that the same may be the case in the small patch near Bulwarree.

Difference between Bijawurs of Jobut and those of Bagh and Dhar forest.

Before concluding this description of the beds of Jobut and Kunas, a few remarks may be made on the differences which they present from the typical Bijawurs of the Dhar forest and Bagh. The jaspery "red bed" certainly resembles the Bijawur hornstone breccias more closely than

it does the beds of any other formation in the neighbourhood, while the schistose slates are represented amongst the beds of Bagh and the sandy calcareous rock in the Dhar forest. Still there is a possibility that the Jobut beds may be distinct, and as one difficulty attending the separation of the Bijawurs from the metamorphics is founded upon the apparent passage of one into the other in this tract, it is as well to point out that absolute proof of the identity of the Jobut rocks with the typical Bijawurs can scarcely be said to exist. The great resemblance of the peculiar red rock of Bulwarree to that so typical of the Jobut beds has already been remarked upon.

Cretaceous beds west of Kunas.

Proceeding now to the west from Kunas, the cretaceous beds are found to continue very thinly developed along the edge of the traps. They certainly do not exceed 100 feet in thickness anywhere, and their average development is probably not above 50 feet. As usual, they are calcareous and conglomeritic near the top. Large cherty masses abound in the uppermost calcareous beds on the road leading from Kunas to Eatara and Rajpoor, near the village of Kilano. Blocks of chert 1 and 2 feet in diameter which have weathered out abound at the surface.

End of Malwa trap plateau.

At Borree the end of the trap hills which mark the Malwa plateau is reached, but the trap itself extends over the flat ground to beyond Kunas. Here the boundary of the metamorphics turns to the northward, and only outliers of the traps occur farther to the westward. This spot is, in fact, the extreme south-west limit of the great trappean plateau of Malwa, which stretches, without a single break, from this spot to the Vindhyan scarp south of Bhopal.

Country between Kunas and Bhabra.

A great flat formed of the thin band of sandstone, upon which rest equally thin outliers of trap, occupies the greater portion of the country between Kunas and Bhabra. The surface of the metamorphics beneath the cretaceous beds is evidently

somewhat uneven, and ridges of it occasionally rise above the general level of the sandstone.

Character of metamorphics.

Towards Bhabra and Chandpoor, the metamorphic rocks become more granitoid and largely crystalline, all traces of foliation being frequently lost. The whole tract from Bhabra to near Kudwal, and apparently even to Godra in the Panch Mehals, consist of this highly granitoid type of the metamorphics, and all the pegmatitic varieties of granitoid gneiss abound. Other metamorphic rocks occur, but those above mentioned predominate. The country is hilly, the hills being frequently composed of huge dome-shaped masses with immense curved faces due to exfoliation, or the surface of the hill is composed of huge weathered blocks.

Mundar hills.

Throughout the tract, however, traces of foliation may be detected here and there. Foliated limestone and hornblend rock occur occasionally. The strike here becomes nearly west-north-west, and many of the ranges of hills take this direction. Such is the case in the hills north and south of Mundar. A few miles north-west of Mundar there is a peculiar pillar-shaped peak known as Ardaseer hill, composed of granitic gneiss.

Band of crystalline limestone.

Along the south side of the Mundar hills is a great band of highly crystalline limestone, containing granular greenish serpentine in considerable quantities, together with a small quantity of bronze mica and specks of a black mineral, probably magnetic iron. Besides all these, crystals of a transparent white felspar form, in places, no inconsiderable portion of the mass. The felspar and serpentine weather out on the exposed surfaces.

This band, which appears to be some hundreds of feet in breadth, may be traced for at least 5 or 6 miles, and a similar band, probably a continuation of the same, re-appears west of Kutteewara.

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This band, which appears to be some hundreds of feet in breadth, may be traced for at least 5 or 6 miles, and a similar band, probably a continuation of the same, re-appears west of Kutteewara.

Other similar bands, also in the foliation strike of the gneiss, are met with near Deokee Hattee, north of Chota Oodipoor, on the banks of the Orsing river.

The Mundar ranges break up about Kutteewara, but others keeping the same general strike replace them, the whole series of hills forming the watershed between the feeders of the Nerbudda (or of its tributary the Orsing) and those of the Mhye. The highest part of all is a table land called Ruttunmul, the flat top of which gives it the appearance from a distance of being formed of trap. Its summit, however, consists of an outlier, about 4 or 5 miles in extreme length, of cretaceous sandstone, caps of the same remaining upon two at least of the adjoining hills. The beds are only about 100 feet in thickness, but they vary somewhat, and portions may slightly exceed that amount, as, although their surface is remarkably level, they rest upon an uneven base of granitoid gneiss. No trap whatever was met with on the top of the terrace; it is strange, if it ever existed there, that it should have entirely disappeared, but it is difficult to say if it ever existed. This occurrence of the cretaceous rocks, at so much greater an elevation than in the neighbouring country, must be due to disturbance. It shews that the southerly dip is not confined to the immediate neighbourhood of the Nerbudda.

Ruttunmul.

Near Oodipoor the strike of the granitoid gneiss appears to be irregular. So far as it can be made out in the Orsing a little above the town, it appears to dip to the north-west, and the same takes place in the hills to the east, but it is not clear that this is not original bedding, as a partial cleavage was distinctly seen in the stream section in one instance with the normal north-west south-east strike, and a little further north, the limestone bands near Deokee Hattee run in that direction.

Gneiss near Chota Oodipoor.

SECTION 11.—NERBUDDA VALLEY NORTH OF THE RIVER; FROM CHOTA OODIPOOR, PANWUD, KAWAT AND HAMP ON THE EAST TO THE ALLUVIAL PLAINS OF BARODA ON THE WEST.

General distribution of rocks.

In this tract, as in the last described, metamorphic rocks prevail to the north, traps to the south. The boundary of the latter to the westward turns rapidly south, while the cretaceous beds become largely developed. The country to the north-west from Jumbooghora and Narookot to Champaneer and Powagurh hill will be described in a separate section.

The gneiss from Chota Oodipoor to Jumbooghora is the same granitoid, highly crystalline rock which is found east of the first named place, no trace of foliation in general being visible; but where such can be distinguished, which is very rarely the case, it has a tendency apparently to a north-west-south-east direction. This tract deserves no especial notice, and presents no character of interest.

A small patch of cretaceous beds intervenes between the traps and the metamorphics close to Panwud. Thence to the west, for a long distance, traps rest directly on the crystalline rocks.

The only interesting portion of this section is the southern, consisting of trap, with some small but instructive inliers of cretaceous rocks: of these a larger number doubtless exist than have been mapped, but it is believed that all of any size have been laid down. The traps of this country are also very interesting, ash beds prevailing to a greater extent than usual, and beds of unquestionably sedimentary origin, yet differing from the lacustrine deposits of Central India, being intercalated in places.

There are two principal cretaceous inliers both close to Kawat. In the more eastwardly of these a fair section of the beds of which it is composed is seen in the Kurro stream, and will be detailed presently.

Cretaceous inlier south of Kawat.

Nature of north boundary.

It is far from clear how this inlier occurs. As the beds throughout dip to the south, and the north boundary is nearly a straight line, along which beds, somewhat low in the series, abut against the traps, the most natural conclusion would be that the northern boundary is a fault with an upthrow to the south bringing up the cretaceous rocks. East of the Kurro, where the boundary strikes east-20°-south, for about 1½ miles, this appears undoubtedly to be the case, for two silicious and calcareous veins which occur in the traps are suddenly cut off by the sandstone, which could scarcely be the case if the boundary were natural and the traps consolidated against a denuded ridge of cretaceous sandstone, in which case a crack subsequently formed in the trap would, in all probability, extend for some distance at least into the sandstone. There are also other indications of faulting, the beds of sandstone being turned up and cut off along the boundary. But west of the Kurro, there is, for some distance, a ridge of sandstone, between which and the stream there is a deep curve in the boundary, and another similar curve is seen two miles further west, just west of Karkunpoor. The ridge of sandstone just mentioned runs very steadily from the one curve to the other, the beds dipping to the south. The curves are certainly opposed to the idea of the boundary being a fault, but the evidence is not quite so perfect as might be desired, the ground near the Kurro especially, being much concealed by alluvial deposits.

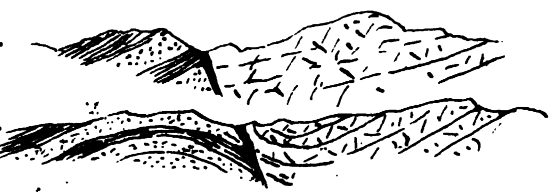
West of Karkunpoor thin flaky sandstone, with minute laminæ of purple clay, and some intercalated calcareous flaggy bands is seen, dipping at about 10° to south-15°-east. Just west of the stream which runs from the south, close to the village, the trap is seen to rest, apparently naturally, though of course quite unconformably, upon these beds, masses of volcanic ash appearing to fill hollows in the sandstone.

West of Karkunpoor the ash beds are seen for a considerable distance, dipping more sharply than usual towards the cretaceous rocks, the boundary of which continues steadily to the south-west as far as the village of Suriwasan. There the sandstones dip sharply away from the trap. If the north boundary of the cretaceous beds were a fault, with the downthrow to the north, a reversal of both these dips might have been anticipated. The present dip is somewhat as in Fig. 15 (*a*)

(Fig. 15).

(*a*).

(*b*).



whereas, with a fault, something of the kind shown in (*b*) might have been expected.

If, as appears probable, the whole inlier is merely a mass of undenuded rock, the adjacent portions of the beds having been removed in pre-trappean times, this is the most marked case of unconformity between the traps and the cretaceous beds which has been observed.

The rocks seen in ascending order in the Kurro are the following from north to south :—

1. Altered sandstone close to the junction :
2. Ferruginous gritty clay, somewhat resembling laterite :
3. Sandstone.—The dip of the above, which are very ill seen, is about S. 20° E. Upon them are the following; the sequence was not sufficiently consecutive for measurement :

4. Alternations of fine and coarse and gritty sandstone, with bands of conglomerate and of sandy clay—the latter more or less nodular, mottled with ferruginous markings, and containing highly ferruginous gritty concretions. In the conglomeritic bands are rolled pieces of ironstone, apparently of oxydised clay iron ore, together with small quartz pebbles. Just above one of the clay bands there is a bed, 4 to 5 feet thick, of ironstone, apparently a sandy red hæmatite, which appears to be so rich that it might be worked as an ore.

The above beds dip at angles varying from 5° to 20°, to south-20°-east.

5. Fine sandstone dipping S. E. at about 5°:
6. Massive grits, chiefly composed of quartz sands much false bedded and white in colour, resembling some of the coarser beds of the Damudas, except that, as a rule, they are harder and less felspathic:
7. Massive fine white sandstone, speckled yellow, somewhat gritty, with interstratifications of yellow shales. Millstones are cut from these beds, which being free from joints and not difficult to work, are well adapted for building stones. Blocks of great size might be procured. Dip. 10° to S. 25° E.:
8. Thin sandy shales and calcareous flags containing oysters. In these there is a band of nodular limestone:
9. Hard coarse grits and conglomerates.

A small fault appears to occur here, and trap is brought in. This may be due, however, not to faulting, but to unconformable superposition. Trap continues for 40 or 50 feet; then beds similar to the last are repeated, and upon them, fine massive sandstone with shaly sandstone resting upon it. This is the highest bed seen, and it is covered by trap.

Thickness exposed.

The above section extends for a mile, and as the average dip is not less than 7°, there must be 600 or 700 feet of beds exposed, unless some unseen fault produces a repetition. It will be seen hereafter that this is not nearly the full thickness of these rocks as exposed some distance further, about 25 miles to the south-west.

Southern boundary.

The southern boundary of this small patch of cretaceous beds is extremely interesting. Near the Kurro the traps are apparently conformable; just beneath them are the calcareous bands with oysters, which, west of Chota Oodipoor, are very characteristic of the uppermost cretaceous beds. Despite the general conformity, however, the dip of the trap appears to be lower than that of the sandstone.

Sedimentary beds at base of traps.

A little further west, near Chiklee Nanee,* there is some difficulty in determining the boundary between the trappean and the cretaceous series, the bottom beds of the former being mostly sedimentary!

Some of the ash beds above mentioned as occurring north of the cretaceous rocks near Karkunpoor have also a sedimentary appearance, and contain fragments of quartz. About Chiklee Nanee, the lowest trappean beds contain, amongst other substances, rolled pieces of trap. The rocks vary much in appearance. Thus, beneath the most southern portion of the village, which is scattered for about a mile along a small valley, a section is exposed in the bank of a little nullah, in which the rock is an ashy conglomerate, composed of alternations of soft, volcanic ash, with harder bands containing sand and small pebbles. These beds, just at this spot, have a sharp dip of about 35° to west-30°-north the cause of which is not evident.

On the other or western side of the little valley, not 100 yards from this spot, the hill side is formed of sandstones and sandy grits, and especially of a quartzose gritty rock, with red or yellow ochre in the interstices between the grains of quartz sand of which it is composed.

* Nanee and Motee (or Nana and Mota) are applied to names of villages in districts where Gujrati is spoken, just as Chota and Bara are applied in Hindustan, and mean little and big respectively.

These beds so strongly resemble the cretaceous rocks that the first impression on examining them is that the latter have been brought up by a fault, to which, moreover, the high dips just noted might be attributed.

Proofs of the sedimentary beds belonging to the trap series.

But on closer examination, all the sandstone and sandy shale is found to contain more or less of trappean detritus or volcanic scoria; conglomeritic ash, containing rounded fragments of trap, is distinctly interstratified, and a massive bed of hard trap underlies them. The latter, so far as anything is seen at this spot, might be intrusive, but further to the west, near Ghantol, where the sandy and ashy beds are of great thickness, and comprise fine red sandstone, and even a band of compact limestone, their base clearly rests upon a thick trap flow, which again rests upon the uppermost beds of the cretaceous series. That the latter are the uppermost beds is shown by their character,—sandy or even finely conglomeritic and calcareous, and by the presence of oysters.

There is evidently a passage amongst these sedimentary beds of the trap, and that within a short distance, from almost pure sandstone to ordinary volcanic ash, and the sandstones of one side of the Chiklee valley evidently correspond to the ashy beds on the other side. That all or nearly all are sedimentary is clear.

Hornblend and augite crystals, such as are occasionally showered out of volcanoes, occur in these strata. In some places the beds attain a thickness of certainly not less than 200 feet.

It is very clear that all these sedimentary beds belong to the trap. They have very much the appearance of the detritus filling river beds, and it seems highly probable that streams hollowed out valleys in the trap flows, and partially filled them again with rolled stones mixed with volcanic ash in the space of time intervening between successive flows of lava.

Probable origin of these sedimentary beds.

It is probable that the thick trap bed near Ghantol may have formed a dam behind which the conglomeritic and ashy beds accumulated. They thin out apparently both in that direction and to the east, and only extend over a breadth of two or three miles, such as might easily be the dimensions of an ordinary river valley.

Intrusive trap near Ghantol.

Trap is seen within the cretaceous beds near Ghantol, but it is evidently intrusive. It is a massive crystalline black basalt, very compact, with small crystals of felspar. A little further west, a small fault, running north and south with an upthrow to the east, cuts across the little patch of cretaceous beds, here not above half a mile wide, and not far beyond they are covered up by trap.

Inlier north-west of that last described.

Another long narrow patch of cretaceous beds occurs just north-west of that last described; it has a similar southern dip, and presents, in many respects, a repetition of the same phenomena. The northern boundary extends for about 7 miles in a straight line throughout and may be a fault, but clear evidence is wanting.

Fault probably existing between two inliers.

The beds are mostly hard sandstones, as usual. Ferruginous lateritic clay is met with as in the Kurro. As in the inlier last described the conglomeritic sandy limestone occasionally forms the uppermost beds, especially towards the west, so that a fault throwing down the sandstone to the north-west probably intervenes between this and the other patch. Without supposing a fault to exist it is not easy to conceive how the same bed can occur at horizons so different as those of the upper beds of the two patches.

Supposing the accompanying section (Fig. 16) to represent the

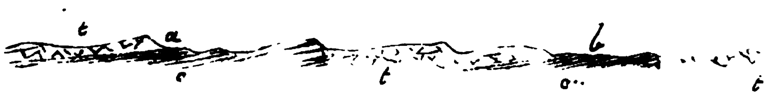


Fig. 16. *c*, cretaceous beds: *t*, traps.

ground, it is evident that if the beds at *a* and those at *b* are the same, a fault must intervene.

But if a fault does intervene, why should this not be the north boundary of the south-east patch of sandstone? The reasons for doubting the fault nature of this have already been given, and it appears probable that the fault may have been of pre-trappean age.

Ashy sandstone and conglomerate and inliers of cretaceous beds south of the above.

South of these patches of sandstones, in the mass of hills which intervene between the Nerbudda and the flat ground watered by the Kurro and other branches of the Hiran stream, there are many beds of the ashy sandstone and conglomerate already mentioned, and also occasional small patches of cretaceous sandstone, so irregular in their mode of occurrence that they are evidently in part brought up by faults.

A few miles south of the Chiklee Nanee before mentioned, an ashy conglomerate is largely developed on the banks of a tributary of the Kurro, between the villages of Mogra and Nakhal, and about half a mile north of the former. It contains rolled and angular fragments of various rocks, comprising altered sandstones, slate, and quartzite in small quantities, crystalline marble with octohedral crystals of magnetic iron, (a rock not observed in the district), and, above all, of trap. The matrix is mainly trappean, with hornblend crystals, and has the appearance of ash. It is excessively difficult, if not impossible in the semi-decomposed condition in which these "ashy" beds occur at the surface, to ascertain whether the matrix consists of small rolled fragments of trap or of volcanic scoriæ. The latter, which is so largely showered out during volcanic eruptions, would be, of course, swept in quantities into any stream which might exist.

The conglomerate just mentioned is distinctly seen to rest upon trap. It must be some hundreds of feet above the base of the volcanic series. A similar bed, also overlying trap, is met with about three miles further east at Boojur on the Kurro. It abounds in rounded fragments of sandstone derived from the cretaceous rocks.

A little south of Boojur, close to Chiklee Motee, a small patch of cretaceous limestone appears from beneath the trap. It is barely 100 yards long, and is brought up on the south by a fault, the beds dipping north on the limestone. A *Hemiaster* occurred with the oysters which are so common in this part of the country, where the Bagh Echinoderms seem to be excessively rare.

Inlier near Chiklee Motee.

Similar small patches appear to abound throughout this country; two or three were seen between Padwani and Mogra. Large fragments of sandstone were observed in a stream near Hamp, evidently brought from the south side of the hill on which Ambadoongur stands, and blocks of the same are scattered in many places over the country. In the latter case they may frequently have been derived from the trappean conglomerate already described, the surface of which at Boojur is covered with such blocks, owing to their superior power of resisting denudation, when compared with the traps. To have searched out and mapped all these small inliers would have been the work of months.

The ash conglomerate is also largely developed. It is evident that the sandstones about Mogra, &c., are at a much higher level than at the Kurro near Kawat, and as their dip is there for the most part to the south, the difference must be due either to a great change in the dip or to faulting. The traps dip generally to the south, so the latter is more probable. The faulting may of course have been anterior, in part at least, to the deposition of the traps.

Close to Padwani, and north-east of Kotebee, there is a very irregular little patch of cretaceous rocks. In a small stream running towards the west sandstone is seen in place for a short distance. Just south of the stream is a hill of a peculiar porphyry, and beyond that again much sandstone and calcareous shale are seen lying about, part of which appears to be in place.

Near Padwani.

The intervening hill is of a peculiar light grey prophyritic trap, resembling trachyte, and in great measure composed of finely disseminated zeolite, probably a form of natrolite. Scattered throughout the rock are small crystals of black hornblend, six sided prisms with trihedral summits, varying in length, some of them acicular, others short and blunt. This trap also contains small angular fragments of other rocks, evidently altered. Close by is a mass of basalt, containing fragments of quartz, half melted into and permeated by the trap. All around is ash, resting upon the sandstone, and frequently itself sandy and mixed with sediment.

The porphyry and the basalt with quartz fragments are, in all probability, intrusive; the sandstones are much disturbed, and the spot may very possibly have been the site of a volcanic outburst. The very large proportion of ash beds in this neighbourhood, and the frequent occurrence of masses of intrusive trap, seem clearly to indicate a centre of igneous action, perhaps part of the great volcanic focus of the Rajpeepla hills.

Evidence of a volcanic centre.

All these hills of volcanic ash are highly fertile, and they are frequently cultivated to their summits.

Returning from the hills northward into the plain country of Kawat, and proceeding westwards down the valley of the Kurro and Hiran streams, all is trap for a long distance, no patches of sandstone occurring. Conglomeritic ashy beds, though far less common than in the hills to the south, are occasionally met with. A section of one such band is seen in the Kurro near Singulda. It contains rounded masses of various kinds of trap, including most of the ordinary varieties, also of granite, metamorphic quartzite, and slate. The fragments of trap are just as much rounded as those of other rocks. The abundance of the fragments of metamorphic rocks is noteworthy, as it proves that the whole country when this bed was deposited was not covered by

Character of country near Kawat.

Conglomeritic bed near Singulda.

the traps, although the band in question is some distance above the base of the series; and as the only rocks seen below the traps to the south are sandstones, it is probable that the detritus in this and other instances was derived from the north. The quartzite and slate fragments must also, in all probability, have been derived from that direction, from the neighbourhood of Jumbooghora and Champaneer.

Direction whence detritus was probably derived.

The neighbourhood of Matapenai (or Kurali) hill is of considerable interest. The hill itself is a craggy peak, of a highly crystalline, greyish trachyte, having somewhat the appearance of a felstone, and composed, mainly, to all appearance, of felspar, with interspersed augite. Scattered throughout the mass are huge blocks of granite; these, towards the top of the hill, are so abundant that it might easily be supposed that the metamorphics cropped out there. Many of these blocks are of great size; some almost form small hills by themselves; one mass on the south side of Matapenai is peculiarly conspicuous. To the east the hill ends abruptly, metamorphics occurring at the foot and extending to the north. To the west a long spur extends, composed of interstratifications of very hard ash breccia and of ordinary basaltic flows.

Matapenai hill.

In the section exposed in the Hiran stream, north-east of the hill, metamorphic rocks extend for a considerable distance. In this direction also, the trap, near the village of Sodawud, contains fragments of granite, some of them of great size, and in one place, on the south bank of the Hiran, *a small dyke of granite is seen intersecting the trap.* It is fine grained, and contains very small plates of black mica; the breadth is about 15 inches, and the dyke can be traced for about 6 yards, while small veins, ½ inch to an inch broad, are given off from it and ramify through the trap. Small fragments of trap are contained in the granite dyke.

Section in Hiran stream.

Dyke of granite in trap.

Farther down the stream dykes of felspathic trap, like that of Matapenai hill, intersect the ordinary trap. Ash conglomerates also occur, the pebbles being chiefly trappean, with only a few of granite. Just opposite to Ooched, also, masses of granite and small dykes of the same rock occur in the trap. The trap passes into a highly crystalline variety, composed of felspar and either augite or hornblend,—it is difficult to determine which.

Matapenai hill apparently the core of a volcano.

The only explanation which suggests itself for these very unusual phenomena is that here, as in one or two other instances noted, the nucleus of one of the great volcanoes of the Deccan trap period is exposed. There is clearly a great intrusive mass of trap which has carried up the blocks of granite with it, and its highly crystalline structure points to slow cooling. The occurrence of small veins of granite in the trap is not easily accounted for. Some of the blocks of granite may have been fused and injected into previously consolidated trap, but it is not easy to understand how so acid a rock as granite could co-exist in the fused state with a basic rock like dolerite. Where granite blocks are contained in trap, as at Mundlaisur and on Matapenai hill, they always appear to have combined with the trap on their edges.*

Outliers on Men river.

A few small inliers of sandstone occur on the Men river. They are mostly of small size and unimportant, and consist mainly of conglomeritic sandstone.

Sandstone on boundary of metamorphics west of Panwud.

Sandstone of cretaceous age, as has already been shown, is wanting along the boundary between the traps and metamorphics for a long distance west of Panwud, and is not even seen near Matapenai hill. It appears close to Wasna on the Hiran river, and occupies a considerable area south and south-west of that place, disappearing to the west beneath the alluvium,

* The granite veins might possibly be due to aqueous action, but the veins could scarcely from their form have been open cracks, and the source of a rock of the composition of granite is the difficulty.

which conceals a large portion of the surface, even up to the trap boundary.

Rocks near Shihadra, south of Wasna.

Close to the right bank of the Hiran near the village of Shihadra, a mile south of Wasna, conglomerates of milk-white quartz pebbles are seen in an almost purely quartzose matrix, coarse, gritty, and white. The beds dip at about 10° to south-10°-west. Fine sandstones are interstratified with the conglomerate, and upon them rest deep purplish, nodular, ferruginous sandstone, somewhat shaly in parts, with dark grey shaly, soft, felspathic, and nodular calcareous sandstones. All these beds are near to the base of the cretaceous series, the metamorphics coming in just below them in the Hiran, and they are unfossiliferous, as the basement beds of the cretaceous rocks usually are.

On Aswun river.

The next stream to the south, the Aswun, flows for a considerable distance through the cretaceous beds. They roll about at low angles, with, however, a general low south or south-east dip.

West of Uggur.

To the west of Uggur, the principal beds seen are fine and very hard sandstones, precisely like those in the Deva near Doomkhul, south of the Nerbudda. Softer beds are only exposed to the east. Close to Wajeria, some hills of granitic rock, at the boundary of the cretaceous and metamorphic beds, are capped by massive conglomerates, hard and gritty, doubtless identical with those seen at Wasna. This band of conglomerate is very similar to the Mahadeva conglomerates of the Nerbudda valley.

East of Uggur.

East of Uggur, about a mile south-east of Nuswadee, hills of conglomerate are met with near the trap boundary, which belong to beds much higher in the cretaceous series than those just described. The rock near Nuswadee resembles that seen in the small inliers at Nowgama and elsewhere near the Men. The pebbles, instead of being all, or nearly all, of white quartz, as in the conglomerate at the base of the series, comprise slates and several forms of

metamorphic rocks, besides quartzite and red jasper. This conglomerate, in fact, precisely resembles that of the Dhar forest.

It is probable that the traps between Wasna and Nuswadee rests upon beds low in the cretaceous series, the upper members having either been denuded, or having never been deposited. In the Men river, near Kukoowasan, the upper fossiliferous beds come in below the trap, and the tract of sandstone south-east of the Men appears to consist principally of these beds, but they are rarely exposed at the surface, there being generally a thick alluvial covering. At Kukoowasan, in the bed of the Men, the uppermost twenty feet below the trap consist of alternations of nodular limestone with white earthy and rubbly beds, also calcareous. These beds abound in fossils which are, however, much crushed and ill-preserved. Oysters predominate, a few *Gasteropoda,* not in sufficiently good state of preservation to be identified, and a plate of a *Cidaris* were also found.

Near Kukoowasan.

Below the limestone comes fine purplish grit, and then massive sandstone and conglomerate. All these beds appear to dip nearly conformably beneath the trap at about 10° to south-30°-east. A bend above Kukoowasan again takes the course of the river for a short distance out of the traps, and exposes the same upper beds of the cretaceous series.

Between the Aswun near Uggur and the Men river all the rocks are concealed by alluvium. In the Men, at Ulun or Ulwun, bluish purple shales with numerous small irregular calcareous nodules and coarse soft sandstones are seen dipping at about 15° to the south-east. About 100 yards further south, on the road leading to Gundeshwar, coarse thick massive sandstones occur, almost horizontal. Resting upon these are flaggy calcareous beds, associated with yellow shales, about 50 or 60 feet thick, and abounding with oysters of at least two different forms, one somewhat triangular, the other long and oval. In the shales are fragments of plants and marks resembling the tracks of small Crustacea.

South of the Men near Ulun.

South of the Men, nearly as far as the Nerbudda, very little rock is seen; the boundary of the trap has, for the most part, to be inferred from scattered fragments, or from the change in the colour of the soil. Where rock is seen, it is generally some form of calcareous shale, frequently containing oysters. Fragments of sandstone are scattered over the whole country, even where the underlying rock is trap. It is probable that small outliers of sandstone occur within the trap boundary, but they must be of very small extent.

North of Gundeshwar.

Near Bhadurwa, north of Gundeshwar, there is a low ridge of gritty sandstone, dipping at a low angle to the south. To the east of this are some low ridges of slightly fossiliferous limestone. Traps come in to the south upon these beds. Fossiliferous strata containing shark's teeth are met with in the Men, near the village of Dohud.

Thickness of cretaceous rocks.

The thickness of the cretaceous rocks exposed in this tract of country appears much greater than elsewhere in the lower Nerbudda area, west of the Hoshungabad district. To the south, in the Deva, a great thickness occurs (see after), but the base is not exposed. Owing, however, to the imperfection of the sections, and the great extent to which the surface of the country is concealed by alluvium, it is impossible to say what vertical thickness of rocks may exist between Wasna and Gundeshwar. Their outcrop extends for 8 or 9 miles; their dip, wherever well exposed, is to the south and not below 5°, but local irregularities and rolling prevent even an approximate estimate of their thickness from being formed with any reasonable prospect of accuracy.

From Barr to Wurgam, the river Nerbudda runs through a deep narrow channel cut in massive trap, frequently columnar, and resembling the thick beds at the base of the Malwa Ghats.

Section in Nerbudda.

Two inliers of cretaceous rocks occur in the Nerbudda between Gundeshwar and Soorpan. Both appear to be brought up by faults.

containing felspar and chlorite, and resembling basaltic trap in external appearance. Some hornblendic greenstones also occur.

South of the belt of hills near Kudwal, and around Jumbooghora, nearly all the surface is composed of granite, passing occasionally into granitoid gneiss. North-west and west of this plain, the hills of Narookot, Dandiapoora, &c., consist of the quartzite and conglomerate of the Champaneer group. South-west of Jumbooghora the rocks, although somewhat similar in composition, are more highly metamorphosed, the bedding in places, as near Peepia, being obliterated. In Massabar hill near Peepia, a spur running to the east consists of very quartzose gneiss, containing large rounded masses of quartz and other rocks. It is evidently a metamorphosed conglomerate, and a rock of precisely similar constitution, though unaltered, abounds in the Champaneer beds.

Near Jumbooghora and Narookot.

Metamorphic conglomerate in Massabar hill.

Some good exposures of the Champaneer beds are seen on the road from Jumbooghora to Soorajpoor. The range of hills north of the road, at the extremity of which is Narookot, is formed of a fine granular quartzite-sandstone, vertical or dipping at a very high angle to the southward. Similar rocks form the hills to the north near Dandiapoora, &c., and indeed the latter have much the appearance of being composed of the same great bed, which rolls over to the north of the Narookot range and then appears to turn up again.

Narookot hills.

South of Narookot granite and gneiss occur in the valley, and in the hills to the south, but at Anandpoor slates and conglomerates come in, vertical or dipping south, and apparently resting upon the quartzites of the Narookot range. They are probably faulted against the gneiss. The slates are in places well cleaved and fine grained, and might afford good roofing slate.

Conglomerates form a ridge of hills south of the road as far as the village of Jhubban; there they twist round, conformably to the underlying quartzite, and dip west. Upon them, south of Anandpoor, a series of quartzites rests, having

Rocks near Jhubban.

a very crystalline appearance in parts, and interstratified with schistose shaley beds. These have the same southerly dip as the conglomerates. But on their strike to the east, granite and gneiss appear, and in this case, as in some others, it is difficult to decide whether the change is due to faulting, or to the metamorphism of the quartzites and schistose beds. Granitic rocks also come in to the south.

West of Jhubban.

West of Jhubban gritty quartzite sandstone rests upon the conglomerate band; the cleavage, which is ill seen, striking west-20°-north, vertical. Next in ascending order are black clay slates, followed by black calcareous beds, dipping to the north-west and with the same cleavage as above. Above these are well cleaved purple slaty beds, containing crystals of magnetic iron.

Near Soorajpoor.

Near Soorajpoor quartzite-sandstone is met with associated with bands of impure magnetic iron, for the most part earthy, and containing much manganese. They dip north-40°-west at a varying angle, generally about 35°. Just on the road but little limestone is seen, but following the strike of the beds to the north-west, it comes in in large quantities, being tolerably pure in places, but generally silicious, and containing quartzose laminæ.

North of Soorajpoor.

North of Soorajpoor the range of hills consists partly of quartzite with ferruginous bands, but chiefly of unaltered sandstone and shale, more or less cleaved. Amongst the rocks are some white and very felspathic grits, with the felspar altered into kaolin. The rocks here shew none of the alteration and crystalline structure which are seen about Jumbooghora and Kudwal. The cleavage is about west-20°-north.

Quartzite near Talaodi and Dharva.

Near Talaodi and Dharva, apparently resting upon the beds just described, a ridge of hard quartzite is met with, the continuation to the west of that already mentioned as occurring south of the Kudwal valley. The beds composing this ridge dip at a very high angle to the north, and are, in fact, almost vertical. The quartzites are hard, almost metamorphic in appearance, compact,

breaking with a conchoidal fracture, and homogeneous, except where cut by quartz veins, which they are to a large extent.

Country to north towards Godra.

Further to the north, the country has not been examined in any detail, but a hasty traverse shewed that Champaneer beds and metamorphics alternated for some distance. Near Godra all the surface consists of the latter series.

Section in upper part of Deo river.

Between Soorajpoor and Powagurh hill but few rocks are seen, except in the upper part of the Deo stream, where a good section of the Champaneer beds is exposed. All are very slaty. Near Dabun schistose slates and calcareous slates occur, dipping at 40° to north-25°-west, and with cleavage striking west-25° to 35°-north. The calcareous beds are absolutely unaltered, except by cleavage, the direction of which near Bhameria changes to west-15°-north.

Outlier of cretaceous rocks near Bhameria.

Just north of Bhameria a little conglomerate occurs. It is evidently a small outlier of the cretaceous beds. To the south of this is quartzite-sandstone, (belonging to the Champaneer group), dipping north by east at high angles, rippled on the surfaces of the slabs, and in places exhibiting oblique lamination. The beds are white and somewhat felspathic; the felspar decomposed.

Granite near Soodra.

Near Soodra granite or granitic gneiss comes in, with lamination parallel to the cleavage of the Champaneer beds. Further south, near Javunpoor, hills of compact quartzite occur.

Near Sonepoor.

All around Sonepoor is highly granitic, and the whole country to the east of that village is similar, completely cutting off the Champaneer beds. But to the south, granular quartzite, apparently belonging to that group, appears around Dhurrola. South of this again granite reappears, but the Dhurrola ridge joins on the west the range of hills near Sidhul and Gogutpoor, which is of very compact quartzite, somewhat metamorphosed in parts, though at Sidhul slate

Quartzite of Dhurrola, &c.

occurs, with cleavage striking west-20°-north. The range running south-east from Sidhul is also of quartzite, which, near this, dips every way from the granite of Manikpoor, upon which it appears to rest. The last mentioned small ridge of hills runs for some distance out into the alluvium of the Baroda plain. To the south of the ridge, on the road from Manikpoor to Maro, schistose slate occurs, followed by a white quartzite-breccia in a reddish-brown or dull brick-red matrix, silicious and sandy, not jaspideous; this rock much resembles some of the Bijawur breccias.

Sidhul.

Beds near Maro.

It is far from clear that these rocks belong to the Champaneer beds; scarcely anything being seen, except quartzite. Still the probability is in favor of their affinities being with those rocks.

A small patch of cretaceous beds is seen in the Deo river near Moowada; alluvium then comes in, but further down at Viarra some trap is seen.

Cretaceous beds near Moowada.

No trap is met with west of the metamorphics and Champaneer beds to the north of Viarra until the base of Powagurh hill is reached: this immense isolated mass of trap forms a most striking feature in the landscape for many miles around. It is a huge terraced block, rising very steeply to a height of above 2,000 feet, and shews the enormous denudation which has affected the region since the trap period, for Powagurh must have been connected by beds as thick as it is high, or nearly so, with the equally massive beds of the Rajpeepla hills. It is not easy to understand how the whole large intervening tract can have been cleared of trap without marine denudation, and Powagurh may possibly have been an island at one time. A very slight change in the relative levels of sea and land would suffice to render it so again.

Powagurh hill.

The traps of Powagurh, unlike those to the south-east, are perfectly horizontal, and a large portion of them possess a very peculiar mineral character. The number of terraces on the hill side is far greater than usual; there are 20 in a

Peculiar traps of Powagurh.

breaking with a conchoidal fracture, and homogeneous, except where cut by quartz veins, which they are to a large extent.

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Further to the north, the country has not been examined in any detail, but a hasty traverse shewed that Champaneer beds and metamorphics alternated for some distance. Near Godra all the surface consists of the latter series.

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Between Soorajpoor and Powagurh hill but few rocks are seen, except in the upper part of the Deo stream, where a good section of the Champaneer beds is exposed. All are very slaty. Near Dabun schistose slates and calcareous slates occur, dipping at 40° to north-25°-west, and with cleavage striking west-25° to 35°-north. The calcareous beds are absolutely unaltered, except by cleavage, the direction of which near Bhameria changes to west-15°-north.

Outlier of cretaceous rocks near Bhameria.

Just north of Bhameria a little conglomerate occurs. It is evidently a small outlier of the cretaceous beds. To the south of this is quartzite-sandstone, (belonging to the Champaneer group), dipping north by east at high angles, rippled on the surfaces of the slabs, and in places exhibiting oblique lamination. The beds are white and somewhat felspathic; the felspar decomposed.

Granite near Soodra.

Near Soodra granite or granitic gneiss comes in, with lamination parallel to the cleavage of the Champaneer beds. Further south, near Javunpoor, hills of compact quartzite occur.

Near Sonepoor.

All around Sonepoor is highly granitic, and the whole country to the east of that village is similar, completely cutting off the Champaneer beds. But to the south, granular quartzite, apparently belonging to that group, appears around Dhurrola. South of this again granite reappears, but the Dhurrola ridge joins on the west the range of hills near Sidhul and Gogutpoor, which is of very compact quartzite, somewhat metamorphosed in parts, though at Sidhul slate

Quartzite of Dhurrola, &c.

occurs, with cleavage striking west-20°-north. The range running south-east from Sidhul is also of quartzite, which, near this, dips every way from the granite of Manikpoor, upon which it appears to rest. The last mentioned small ridge of hills runs for some distance out into the alluvium of the Baroda plain. To the south of the ridge, on the road from Manikpoor to Maro, schistose slate occurs, followed by a white quartzite-breccia in a reddish-brown or dull brick-red matrix, silicious and sandy, not jaspideous; this rock much resembles some of the Bijawur breccias.

Sidhul.

Beds near Maro.

It is far from clear that these rocks belong to the Champaneer beds; scarcely anything being seen, except quartzite. Still the probability is in favor of their affinities being with those rocks.

A small patch of cretaceous beds is seen in the Deo river near Moowada; alluvium then comes in, but further down at Viarra some trap is seen.

Cretaceous beds near Moowada.

No trap is met with west of the metamorphics and Champaneer beds to the north of Viarra until the base of Powagurh hill is reached: this immense isolated mass of trap forms a most striking feature in the landscape for many miles around. It is a huge terraced block, rising very steeply to a height of above 2,000 feet, and shews the enormous denudation which has affected the region since the trap period, for Powagurh must have been connected by beds as thick as it is high, or nearly so, with the equally massive beds of the Rajpeepla hills. It is not easy to understand how the whole large intervening tract can have been cleared of trap without marine denudation, and Powagurh may possibly have been an island at one time. A very slight change in the relative levels of sea and land would suffice to render it so again.

Powagurh hill.

The traps of Powagurh, unlike those to the south-east, are perfectly horizontal, and a large portion of them possess a very peculiar mineral character. The number of terraces on the hill side is far greater than usual; there are 20 in a

Peculiar traps of Powagurh.

thickness of about 500 feet below the upper flat: only a portion of these are due to the ordinary basaltic lava flows; the remainder consist of a peculiar light purple argillaceous rock, rare elsewhere. It has a somewhat cherty appearance, and generally contains small crystals of glassy felspar: this rock is sometimes mottled, purple and grey; it is almost always distinctly marked by planes of lamination, parallel to the stratification, and sometimes so finely so as to resemble an ordinary shale more than a volcanic rock; yet these beds occasionally appear to pass into basaltic trap, and one form of basalt, that containing crystals of glassy felspar, weathers, at the edges of blocks, into a substance closely resembling the purplish shaley rock just described.

It is not easy to explain the formation of such beds. Frequently they have the appearance of volcanic ash, but, on the other hand, their highly laminated structure appears due to deposition in water; yet it is in places irregular, and the beds contain pumice, which could hardly be expected to occur in subaqueous formations. There is a possibility of these rocks having been flows of volcanic mud of great tenuity, or their peculiar character may, in part at least, be due to changes subsequent to their consolidation. Similar beds are very rare amongst the traps, and no other instance of their development on an equally extensive scale elsewhere has as yet been observed in Western India.

SECTION 13.—AKRANEE AND KANTEE, OR PARVEE; FROM TOORUN MUL ON THE EAST TO THE WESTERN WATERSHED OF THE DEVA RIVER ON THE WEST, AND FROM THE NERBUDDA TO THE NORTHERN BOUNDARY OF KHANDEISH.

General distribution of rocks.

With the exception of a small patch of sandstone and shale towards its western extremity in the valley of the Deva, the section of country now to be described consists entirely of trap. The country is a mass of hills, many of them of considerable height.

Contrary to the general rule in the case of the trap hills, the ridges lying west of Toorun Mul are rarely flat topped, and frequently extremely craggy. The range on the borders of Khandeish is remarkable in this respect. As a rule, the beds dip very slightly, more so however than they do in Malwa or the Deccan.

Unusual form of some of the trap hills.

The traps of Toorun Mul itself are nearly horizontal. To the north-west there is a low east-north-east dip, and this, turning to north-north-east, continues as far as the Oodai river, where the dip is about 6°. These dips frequently can only be seen from a distance upon the hill sides; consequently it is difficult to ascertain their exact direction. Local dips in nullas, &c., are not trustworthy as a rule, the surfaces of the lava flows being very irregular. The traps of the hills along the northern boundary of Khandeish have generally a low northerly dip, but it is not very regular.

Dip of traps.

But few trap dykes occur in Akranee when compared with the country to the west. Around Durgam, however, there are several parallel dykes of small size. Near that village they occur every 200 or 300 yards. They strike east-15°—30°-north, as in Rajpeepla. Some of these dykes are highly crystalline, composed of felspar and granular greenish augite. South of Durgam, where these dykes intersect certain flows of basaltic trap, there is, close to the junction, a great development of the flat tabular crystals of glassy felspar which characterize the porphyritic variety of the basalt. The matrix is a dark grey rock, in which the augitic and felspathic elements are readily distinguished beneath a lens. It is amygdaloidal, containing nodules of carbonate of lime.

Trap dykes.

In the Nerbudda just east of the mouth of the Oodai, a large trap dyke running east-10°-north crosses the river. It contains fragments of quartz and of granitic rock, partly fused into the trap. Other similar dykes occur in the neighbourhood. Masses of metamorphic rocks not unfrequently occur on

Metamorphic fragments in trap.

the trap around this, and, as is the case at Mundlaisur, it is often by no means clear whether the including rock is intrusive or not.

Ash breccias in Nerbudda below Hamp.

Below Hamp, as in the hills north of the river described in Section 11, ash breccias are very abundant amongst the rocks exposed in the river. From these having been cut away by the river's action, fresher sections, exhibiting the structure of the rock, are to be seen than are generally exposed on hill sides. One form consists of a very fine green matrix with white crystalline specks. It contains brown and purple fragments so irregularly mixed that they frequently look as if they had been half fused into the mass. Other fragments are vesicular. Some have evidently originally been pumice, the vesicles now being, in some cases at least, filled with agate.

In some of the light green breccias the matrix is darker in colour than many of the enclosed fragments, the latter being of a light pistachio green, very compact and earthy in general, though occasionally vesicular. Many of these fragments are of considerable size, often 2 or 3 feet in diameter. The colours vary much in patches, and may be due, in great measure, to chemical changes of subsequent date to the consolidation of the rock.

Brecciated calcareous vein near Gudhir.

Close to Gudhir, a brecciated calcareous vein like those so numerous near Burwanee crosses the river. It is, as usual, partly calcareous, partly silicious. The silicious portion is, to all appearance, the older; it is crushed and brecciated and then recemented by a calcareous matrix. It has the same strike as the Burwanee veins, and the trap dykes of Rajpeepla, &c., *viz.*, east-20°—30°-north.

Cretaceous rocks of Deva valley.

It is unnecessary to enter into further details concerning the trap area. The cretaceous rocks of the Deva valley, however, demand some notice. These are well exposed on the banks of the Deva and its tributaries, on which sections of great thickness are seen. The sandstones, in general, are much hardened,

and frequently cut up by dykes and large irregular intrusions of trap, but, despite their much older appearance* and greater thickness, they appear all to be attributable to the Bagh group. Similar sandstones are associated with those beds west of Chota Oodipoor. The uppermost beds near the Deva, too, are calcareous shales, similar to those which occur north of the Nerbudda, and containing the same fossils.

Size of inlier.

This is the largest inlier of the cretaceous rocks met with. According to the map, it is only about 6 miles from north to south, but this is almost certainly less than the real distance. By the only road, which, despite the unevenness of the ground, is not very tortuous, it is at least 12 miles from Doomkhul to Soorpan. The breadth from east to west is about 10 miles. Of the rocks a thickness of nearly 1,000 feet must be exposed, their base not being seen. The beds are but little inclined; they have a quaquaversal dip, sloping away in every direction from the neighbourhood of the village of Atti, east of the Deva. To the west they pass steadily under the traps; the north and south boundaries are faults, and the east boundary may also be a fault, but it has rather the appearance of an abruptly denuded termination, as if the lower traps had been consolidated against a pre-existing sandstone cliff.

Thickness of beds exposed.

Dip.

Boundaries.

Section in Deva.

The section in the Deva gives a fair idea of the rocks; the higher beds, however, not being seen so low as the stream bed. At the junction with the trap close to Doomkhul, hardened white and brown sandstones occur with conglomeritic grits; these beds roll somewhat with a general rather low north-west dip, and are much cut up by trap dykes. They are succeeded in ascending order down the stream by shaly beds, intercalated with hard white sandstone; some of the latter, which are very fine and compact, being marked with

* These were the first rocks belonging to the Bagh beds met with by the survey, and their old hardened appearance induced a suspicion at first that they might be Vindhyans.

small round brown patches, half an inch to an inch in diameter, giving a peculiar appearance to the rock.

For two miles to Kanjee, similar beds occur intersected by dykes and irregular intrusions of trap, often of considerable size. The dip is low and irregular, but in general southerly.

For two miles beyond Kanjee, the sandstones have in general a western dip. The high hill of Soondroo west of the stream is capped by trap, which dips steadily to north or north-west. It is not clear whether the traps here are unconformable on the sandstones.

A stream of considerable size joins the Deva from the west about two miles north of Kanjee. Below the junction, the Deva runs through a deep abrupt gorge in the sandstone, so precipitous in parts that it cannot be traversed. The abrupt cliffs at the side somewhat resemble those in the Mahadeva sandstone of the Puchmurree hills, and the rock is not dissimilar. Oblique lamination prevails largely, so much so that there is a most remarkable appearance of unconformity between the upper and lower beds of the sandstones. There is, throughout this gorge, a general low northerly dip of the rocks. West of the stream they appear by aneroid measurement to rise about 800 feet above its bed upon the sides of the hills, the uppermost 200 feet being principally shale. The absolute thickness of shale, however, varies, and appears to increase towards Doomkhul, where it can scarely be much less than 500 feet. This is perhaps due to the unconformity of the traps upon the cretaceous beds, but it is not certain that there is not also unconformity between the shales and the sandstones.

In the Deva, the north boundary of the cretaceous bed is not seen; half a mile intervenes between the spots where they are exposed and the first appearance of the trap in the stream, the intermediate space being covered with large boulders. To the west, the boundary fault is better seen on the Koorban* stream, and there are some sharp dips in the sandstone in its vicinity.

* A small stream which runs into the Deva from the west close to its mouth.

Further details.

In proceeding to give a few additional details concerning this remarkable inlier of the cretaceous rocks, it will be best to describe, first, the larger area occupied by them to the west of the Deva.

Rocks seen in Koorban stream.

In the neighbourhood of the northern boundary, which runs about west-30°-south up the valley of the Koorban stream, a few beds of red clay occur with the sandstone, similar to those met with further north near Kawat. Further up the stream much shale and shaly limestone occurs, the latter containing oysters, and peculiar ferruginous masses, enclosing *Bryozoa*. Intercalated with the shales at one spot is a horizontal bed of trap, which has the appearance of being interstratified, but is, in all probability, intrusive, like another presently to be noted. A huge mass of intrusive trap is seen close by. The beds dip steadily to the west, and trap covers them up near the village of Mootar.

Rocks near Wandee.

In the next valley to the south, that of the stream flowing past Wandee and Torakhal into the Deva, the rocks seen are principally shales, of which there is a great thickness. They stretch for some distance beyond Wandee, then the steady low west dip brings in the traps. In the shale west of Wandee, another horizontal dyke of trap was seen just north of the stream. On examining this closely, it was found to alter the shales both above and below, and on tracing it for a short distance back from the stream, it was found that its apparent interstratification is only continued for a few yards, and that, just beyond, it cuts through the beds. There can therefore be no doubt of its intrusive nature. The dyke is from 6 to 8 feet in thickness, dark, compact and non-vesicular.

There is much crushing and twisting in the upper shales, just below the traps, west of Wandee.

Soondroo hill.

The top of Soondroo hill north of Doomkhul is of trap. By aneroid measurement, the base of the trap was about 600 feet above the lowest sandstones seen near Doomkhul. The greater portion of this thickness is of shale;

sandstones, however, are interstratified, especially below. *Ostrea* abound in some hard calcareous bands in the shale, but it is almost impossible to extract them in a state sufficiently well preserved for recognition. When first found, which they were at this spot, no specimens were obtained good enough for identification.

Fossils.

The south line of boundary runs east-15° to 20°-north up the valley between Doomkhul and Peeplode, the shales being seen crushed and turned up against it near Kukurbee and elsewhere.

Southern boundary.

East of the Deva, near Soorpan, but a small area is occupied by the cretaceous beds, the top of the high range, called Bawagupnyo, being of trap. Near Warwee, shales with limestone and oyster beds occur, and in the calcareous shale, just below the trap, on the west spur of Bawagupnyo hill, shark's teeth abound in a calcareous black rock, containing irregular silicious masses (? concretionary).

Rocks east of the Deva.

Looking from the hill east of Warwee, there is an appearance of unconformity of the traps upon the cretaceous beds. The former have a steady southerly dip, the latter dip in places north-east and roll in various directions.

Unconformity of traps and cretaceous beds.

The hills east of the Deva, towards Atti, are almost entirely composed of sandstone, a little shale only appearing in places near the summits. Atti itself cannot be less than 1,000 feet above the Deva, and all is sandstone at the village, although the base of the traps cannot be many feet above. This is remarkable, for, as already shewn, at Doomkhul, and even at Torakhal, not more than 4 or 5 miles to the west, 400 or 500 feet of shale occur. But it should be remembered that that shale is largely mixed with sandstone, and it is by no means improbable that the differences may be merely local. There is still a possibility of unconformity between the shales and the sandstone. But, on the whole, the evidence is rather in favour of both belonging to one continuous series.

Rocks near Atti.

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Rocks near Atti.

Mograbari.
Babasiraj.

Further to the east, the sandstone continues steadily, almost horizontal, to the head of the Mograbari stream, north of Babasiraj hill, where it is suddenly overlapped by the trap in the manner already referred to. At the head of the valley all is sandstone, and for about a mile down it is the same, but close to where 200 or 300 feet of sedimentary rocks are seen in the sides of the ravine trap comes in suddenly, occupying the whole valley and covering up everything. The traps certainly have a sharp dip, about 10° to the east, but that is far from sufficient to account for so rapid a disappearance of the underlying beds.

Sudden overlap of cretaceous rocks in Mograbari valley.

Anticlinal seen from Babasiraj hill.

From the top of Babasiraj hill, the finest peak in the country, about 2 or 3 miles south-east of Atti, the general anticlinal seems to have an east and west axis, the traps of the hills, west of Doomkhul and Peeplode, being seen to dip northward and southward, from a line drawn about due west from Atti. To the east, the dip is more steadily south and south-east, which accounts for no cretaceous beds reappearing in Kanti and Akranee.

SECTION 14.—THE RAJPEEPLA HILLS, FROM THE EASTERN WATERSHED OF THE DEVA, SAKHBARA, AND THE WESTERN BOUNDARY OF KHANDEISH TO THE EASTERN EDGE OF THE NUMMULITICS.

General characters.

This tract requires but brief notice. It is entirely composed of trap, and its features do not, as a rule, require detailed description. The most peculiar character, the great disturbance which the traps have undergone, and the prevalence of dykes of large size, have already been mentioned in the chapter devoted especially to the traps.

Range of hills south of Nandod.

Commencing at the north-east, a broad range of hills, attaining a height of between 2,000 and 3,000 feet above the sea, extends from the Deva to the stream which runs past Nandod. West of that stream the range continues, but it is of no great breadth, and gradually loses in height. In their eastern

portion, these hills consist of an anticlinal of the traps, the principal dip, however, being to the south, and the northerly dip only occurring for a short distance near the Nerbudda. The dip in places amounts to 15°, but does not in general exceed 5.°

View from Peeplode hill.

From some of the peaks, as Peeplode hill, a fine panoramic view of this wild, hilly region may be obtained. East and west are ranges of trap hills, not with flat tops as usual, but with sloping surfaces. To the north, the Nerbudda runs in a gorge between the hills. North of the river there is a lower range of trap, beyond which the comparatively flat country of the Hiran and Orsing valley is visible. To the south the hill tops are more level, and a range stretches away towards Sakhbara, the beds forming which have a very low north dip; while to the south-east, the craggy peaks of the Satpooras overlooking the Taptee valley are conspicuous.

Hills near Sakhbara.

The hills south of Peeplode extending thence to Sakhbara were but little examined, and present no characters which require detailed description. In one place, east of Gungapoor, a peculiar semi-crystalline bed, containing small rounded patches of a white amorphous mineral, was met with. It resembled a rock, to be presently described, which occurs at Ooskur, east of Turkesur.

South-west of Sakhbara, the country is a great plain, covered with cotton soil. It is all forest, but might apparently be cultivated, if population existed.

Characters of central portion of Rajpeepla.

The country south of the Peeplode and Rajpeepla range and west of the Sakhbara hills is a wide undulating tract, without high hills, but still far from level. It is here that the numerous trap dykes, so frequently referred to, are most conspicuous; they form small parallel ridges, frequently only 200 or 300 yards distant from each other. They are peculiarly abundant about Khamb, and throughout the country east of the Kurjun river. Their strike varies from east-5°-north—west-5°-south to east-20°-north—west-20°-south.

In the north-west, about Nandod, a broad alluvial tract occurs along the Nerbudda. This is everywhere fertile and cultivated. The ground, except in the immediate neighbourhood of the river, is undulating, as is usually the case on the older alluvium, and only close to the Nerbudda is there a flat of comparatively recent deposits.

Alluvial plain near Nandod.

Along the range of hills south-west of Nandod (the continuation of the Peeplode and Rajpeepla range to the westward), the traps appear to be somewhat irregular in dip. The extreme north-west corner is at Sursho hill, east of Ruttunpoor. The beds of this hill have been greatly tilted up, like the nummulitics close by to the west, and they dip to the north-west at 60°. The rocks are peculiar, one being a conglomeritic breccia, containing angular and subangular masses of sandstone and conglomerate. This is similar to the beds seen south of Kawat. Beneath the breccia is a peculiar fine grained amygdaloid, so fine and amorphous as almost to resemble a pitchstone. Other beds appear to consist of volcanic ash.

Sursho hill.

Some distance south of this and east of Padwani is a hill composed of a light coloured, nearly white rock, containing quartz and felspar, and singularly trachytic in character. It contains fragments (probably crystals, but much decomposed) of an orange felspathic mineral, about ¼ inch in length. This rock has a more trachytic appearance than any other met with amongst the traps of these districts: it forms an isolated mass, only extending about a mile from east to west, and about half as much from north to south. It may be a volcanic nucleus, exposed by denudation. Its extreme extent to the west is not seen, as it is covered in that direction by the nummulitics.

Trachytic rock near Padwani.

Throughout the northern portion of the Rajpeepla country, there has been found a general southern dip of the traps. South of a line drawn through Jubboogam and Sakhbara this is changed, and the dip is either north or west. The

Dip of traps.

last is especially the case to the south-west, and is well exhibited in the Taptee, below Mandvee. This is the commencement of a steady westwardly dip of the traps which continues to the southward, till beyond Bombay.

In the southern portion of the Rajpeepla hills there are only one or two places which need notice. One of these is at Ooskur south-east of Turkesur, where the bed occurs, to which reference has already been made in the chapter upon the tertiary beds, when describing the evidence of unconformity between the nummulitics and the traps. This bed is of very shaly character, at times assuming almost a porcelanic structure. It is lilac grey in colour, and contains minute felspar crystals. It exhibits distinct and fine stratification, much disturbed however, and possibly due to that peculiar agency which causes lines of pseudo-stratification to be so distinctly developed in some beds of basaltic trap. Beds similar to this shaly rock of Ooskur are met with largely in and about Powagurh hill. (See Section 12).

Shaly rock near Ooskur.

The section exhibited by the river Taptee, between Chiklee and Bhodan (near which the nummulitics appear,) deserves a brief description.

Section in Taptee river.

Below Chiklee the Taptee runs in a deep channel cut through the older alluvial deposits, conglomerate and silt capped by regur; conglomerate being less prevalent than in other sections. Trap appears here and there in the bed of the river and dips to the north. All the ground adjoining the river is alluvial, being the western extremity of the alluvial plain of Khandeish.

A large quantity of conglomerate is seen in the small stream which runs past Jharwan into the Taptee. It is seen resting on trap, and is in places 20 to 30 feet thick. It is very hard, and is composed of rounded and subangular fragments of trap and agate, similar to those in the stream bed, cemented by carbonate of lime.

About Wajpoor the traps have no distinct dip. Dykes abound, several of them running east-20°—30°-north as usual. At Wajpoor a large dyke runs along the river for about half a mile in a direction of east-30°-north. It consists of subcrystalline basalt, very heavy, and containing small white grains, either of quartz or agate.

For a long distance below Wajpoor traps abound in the river, but their dip is indistinct. About Pargut the hills appear to be formed of nearly horizontal beds.

From Pargut to Mandvee little of interest is seen in the Taptee. Much trap occurs, but with no distinct dip. There is not much of the calcareous conglomerate, though a considerable quantity is seen just above Mandvee.

In this conglomerate *Melania tuberculata*, Müll., *Bulimus pullus*, Gray, and a small species of *Corbicula* are met with.

From Mandvee westwards, towards Ooska, porphyritic trap occurs, apparently with a slight westwardly dip. Dykes are numerous. Just below Ooska a bed of ash is seen resting on porphyritic basalt and dipping about 3° to the west. Upon it comes amygdaloid.

About Kumlapoor there is a large quantity of rock seen in the river, chiefly beds of amygdaloid, the separate lava flows being apparently very thin. All dip distinctly to the west at a considerable angle, 13°. Some of the amygdaloids are slightly porphyritic. The steady strong western dip continues to below Bhodan, where the nummulitics appear.

Pebbles in bed of Taptee.

The pebbles in the bed of the Taptee, even at Mandvee and below, are not all of trap; a few occur of metamorphic rocks and quartzite. These must come from near Baitool. This shews how certainly the presence of the different rocks, provided they are of considerable hardness, contained in any river valley, may be ascertained by examining the pebbles in the bed of the stream

draining it. In the same manner, in the bed of the Nerbudda near Nandod, a very considerable proportion of the pebbles are of Vindhyan sandstone brought down from above Burwai.

SECTION 15.—SURAT AND BROACH.—COUNTRY BETWEEN THE NERBUDDA AND TAPTEE BORDERING ON THE SEA.

Area.

In this section will be described the whole country between the two rivers from the sea to the border of the trap area in Rajpeepla. It comprises so much of the district of Surat as lies north of the Taptee, the Broach district south of the Nerbudda, the Wusravee pergunnah, and other portions of country belonging to the Gaekwar, and the western portion of the Rajpeepla territory.

Alluvial plain near sea.

Near the sea, and for from 20 to 30 miles inland, no rocks are seen, except in one or two places. The whole country is covered with alluvial clays, which pass generally on the surface into black cotton soil. It is highly fertile and cultivated almost throughout.

Succession of rocks appearing to eastward.

The first rocks to emerge from beneath the alluvium are usually the gravels and clays of the nummulitic series, and from beneath these, somewhat further inland, the traps crop out.

In describing this tract in detail, it will be best to commence at the north and proceed southwards.

Nummulitics near Sursho hill.

For some distance up the Nerbudda, as far east as several miles above Nandod, nearly 40 miles from Broach, there is a broad belt of alluvium to the south of the river, south of which trap rocks appear as far to the west as Sursho hill. Immediately west of the hill beds of the nummulitic series appear: they are much disturbed and dip at high angles. The traps forming Sursho hill also have a very high dip (60° to the north-west).

As no beds whatever are seen north of Sursho hill, it is impossible to ascertain precisely what this disturbance imports, and it is quite uncertain whether the nummulitics lap round the base of the hill and occur in the plain to the north, or whether they are faulted against the trap of the hill; all that can be seen is, that the tertiary beds which to the south have a low westwardly dip, suddenly turn up and dip to the north-west at an angle of 60° to 80°, and immediately disappear beneath the alluvium.

Peculiarities of boundary.

If the boundary be a fault at Sursho hill, and in favour of this view is the fact of the nummulitics being turned on end just south of the hill, the fault soon dies out to the southward; for close to the village of Maldipoor, the bed seen next to the trap (the absolute junction is not seen) is the same as that which forms the base of the tertiary series for some distance to the south, *viz.*, a coarse conglomerate of trap pebbles. This is seen resting upon the trap, wherever sections are exposed, as far south as the village of Amuljhur. The bed is almost entirely composed of large rounded masses of trap, some of them nearly a foot in diameter. The rock so exactly resembles a trap flow disintegrating into concretionary masses that only close examination can detect the difference.

Trap conglomerate near Maldipoor.

In the stream already mentioned near Maldipoor, the following are the basement beds of the nummulitic series. The series is given in descending order:—

Section of basement beds of nummulitics in stream near Maldipoor.

1. Very coarse conglomerate of trap pebbles and deep red clay.
2. Ferruginous mottled clay, approaching soft laterite in appearance.
3. Fine sand with a band of small trap pebbles.
4. Conglomerate of trap and agate pebbles; the matrix of trappean detritus.
5. Coarse sandstone, nodular and concretionary, with argillaceous layers, and one thin band containing trap pebbles.
6. Sandstone, } Both abounding in casts of *Gasteropoda;* no other Mollusca occur,
7. Limestone, } nor any *Nummulites:* of the limestone about 4 or 5 feet are seen.
8. Slightly ferruginous sandstone, soft and coarse, with runs of kunkur intersecting it vertically.
9. Coarse conglomerate of trappean pebbles. This rests upon the trap.

These beds dip to the west; at the base the angle is very high, about 45°; this diminishes gradually above, and the direction changes to west-15°-south. The uppermost beds are much disturbed, and in one place dip to the south.

Near Amuljhur the basement beds are precisely similar to the above.

Higher beds.

Upon these bottom beds rest strata mainly consisting of gravels and conglomerates, the pebbles forming which are chiefly agates evidently derived from the trap. With these, especially towards their base, bands of laterite are associated, but they are thin, and do not assume the importance they have further south. Some beds of laterite dipping at a high angle are seen west of Sursho hill near the village of Bheempoor. Beneath these and associated with some trap gravels are whitish calcareous bands, containing large trunks of fossil wood, the interior structure of which is not well preserved.

Beds south of Bheempoor.

South of Bheempoor, between that village and Boori, near Amod, laterite and agate conglomerates are seen interstratified. This circumstance is worthy of notice, for to the south, near the Taptee, the laterite bands are confined to the basement beds of the series, which are possibly older than these agate conglomerates and gravels to the north.

Highest beds seen in stream near Ruttunpoor.

The highest beds seen in this tract of country are those of the neighbourhood of Ruttunpoor. A fair section is exposed in the stream which runs south of the village. The principal beds are agate gravels sometimes cemented together so as to form conglomerates, with bands of sandstone, argillaceous or calcareous. Fossil wood is found in the conglomerate, and in one place, a shell, apparently a *Helix*, was met with. The section seen in the stream comprises all the upper and middle beds, and in connexion with that already quoted of the lowest beds near

Maldipoor, will furnish some idea of the tertiary rocks of this neighbourhood. The following beds are seen in descending order.

1. Calcareous clays.
2. Agate gravels and conglomerates with fossil wood.
3. Calcareous and argillaceous white sandstones.
4. Agate gravels and conglomerates, with occasional trap pebbles.
5. Ditto, with layers of sand and of red ferruginous clay.
6. Calcareous clays and pale yellow sandstones containing plant remains.
7. Alternations of gravel or conglomerate, sandstone, and red lateritoid clay, with occasionally bands of clay of various colours, and shales.

Each of these extends for a considerable distance and represents some hundreds of feet. It is very difficult to say if all these beds are regularly superposed one upon the other; if they are, the whole thickness must be very great. But possibly these are either faults or concealed rolls of the strata.

Ruttunpoor hill.

Ruttunpoor hill is to the north of the stream. It consists mainly of conglomerate, which dips north-west on the north side of the hill, and in the opposite direction on the south, near Ruttunpoor, so that the extremity of the hill is a small anticlinal. The hill strikes nearly north-east—south-west; and further to the north-east, the dip appears to be chiefly to the north-west, north of the hill, and to the west on the south. There is thus here, as to the west, very considerable disturbance of a later date than eocene.

Agate mines.

South of the hill, between it and the village of Dumlahee, are the well known Ruttunpoor agate or cornelian mines. The agates occur in certain of the gravel beds, and have undoubtedly been originally derived from the trap, as was remarked by Dr. Carter. The only stones considered of value occur in a small ferruginous stratum, from the iron of which their colour is doubtless derived.

South of the Ruttunpoor stream very little rock is seen as far as the next watercourse, the Kaveree. About Dholekoowa agates abound on the surface, and fragments of conglomerate are met with, though no rock is seen in place. Further to the south-west, more conglomerates are seen; the edges of beds, with a high dip, cross above the surface in the continuation of the line of the Ruttunpoor anticlinal.

Rocks near Dholekoowa, &c.

Further to the south low dips prevail, with a general direction to north-west or north.

Returning to the trap boundary near Dumlahee and Padwani very few rocks are seen, and the boundary itself is, in places, obscure. Fragments of conglomerate, of laterite and of a white calcareous sandstone, are seen scattered about. East of Padwani laterite is seen, and a little further east, fossil wood in abundance, but rather ill preserved. All the interior portion of the stems is generally replaced by crystalline calcspar.

Neighbourhood of trap boundary near Padwani.

Where the nummulitics rest upon the trap they consist of argillaceous beds with small trap pebbles, and have a low westwardly dip of 5° to 6°.

Basement beds.

In the Kaveree, the section which is exposed is somewhat similar to that seen in the stream which flows past Ruttunpoor, but it is much less continuous, and more laterite occurs, especially about Wasna, where the dip is very low. Where the laterite beds are cut into by the stream west of the village, they so closely resemble decomposed trap as to be undistinguishable, and are very probably formed of trappean detritus. Another thin ferruginous bed, closely resembling decomposed trap, is seen resting upon white and lilac shales at the village of Wasna. A similar bed, probably identical, is again seen, similarly associated with white and purple shales, about a mile to the south, in a small nulla, where no continuous section can be seen, and where the surface is covered by alluvium.

Section in Kaveree near Wasna.

Below the laterite of Wasna, the white calcareous sandstones and clays which were seen to the north near Bheempoor are again exposed. About half way between Wasna and Bojpoor, another bed of laterite is met with, dipping to the west. It contains pebbles, an unusual circumstance.

Wasna appears to be the locality mentioned by Dr. Carter,* whence Major Fulljames obtained the specimens of nummulitic limestone, which furnished *Nummulites Broachensis*, Carter, and *N. Ramondi*, Defrance, associated with *Operculina* and *Orbitoides dispansus*, Sow. No bed of limestone containing fossils was met with nearer to Wasna than at Wagulkhore, in the Oomrawuttee stream, 3 miles to the south, a locality which will be described presently.

Locality of Dr. Carter's Wasna fossils doubtful.

But it is quite possible that a thin band may have been overlooked, although search was made for it, and it is even by no means improbable that a small section of a stratum may have been exposed in a nulla when Major Fulljames's examined the locality, which was concealed by pebbles or sand during the present examination. It is also possible that Major Fulljames's locality may have been at Wagulkhore or in its neighbourhood.

Section below Wasna.

Below (north-west of) Wasna sandy clays, gravels, and conglomerates are seen at intervals in the Kaveree for a long distance; no good or continuous section being exposed. A few beds of laterite are also seen. Between the Kaveree and Oomrawuttee scarcely any rock is seen in place, the whole country being covered with alluvium.

Section in Oomrawuttee stream.

In the Oomrawuttee trap is seen in place near Amboosh. Thence to Dharolee and Wagulkhore very little rock is met with, the banks of the stream consisting, for the most part, of modern conglomerate of trap pebbles, cemented by

* Geological Papers on Western India, p. 696, note; and Jour. Bombay Branch Roy. As. Soc., Vol. VI, pp. 63, 65, and 164.

carbonate of lime. Some of the nummulitic beds, however, crop out here and there.

Wagulkhore.

At Wagulkhore there is an interesting section. At the base is a thick bed of laterite; next comes yellow clay, upon which rests a bed of pipe clay dug out by the natives, and said to be used to clean cotton thread before dyeing. The next rocks in ascending order are sands, passing upwards into limestone, both ferruginous, and the latter abounding in nummulites, *Gasteropoda* and other fossils. Above these is a band of sandstone, and then laterite again, containing in places pebbles. The matrix containing the pebbles has a strong resemblance to decomposed trap.

Sedimentary origin of laterite.

The peculiar interest of this section, apart from the numerous fossils, is the distinct evidence it affords of the sedimentary origin of the laterite. In one place the fossiliferous stratum is scarcely distinguishable from laterite.*

Bhilod.

The beds near Wagulkhore dip to the north-west at 10°. A little further down the stream, a laterite bed again occurs at Bhilod, just north-east of which clays and ferruginous sandstones are seen dipping at about 50° to west-10°-north. Thence to Limbat very little rock is seen. At Limbat agate conglomerate with argillaceous sandy beds crops out. It is nearly horizontal in the stream, but on the north bank, a bed is seen turned up at a high angle, and dipping at 50° to south-35°-east. There may be faulting; there is certainly a line of disturbance, which may be traced for some distance to the north-east. Some large oysters occur here. The stream runs along the strike of the rocks (north-east south-west) from Limbat to Heerapoor, where soft sandstones, containing hard round concretionary masses and conglomerates,

Limbat and Heerapoor.

* Yet the laterite so closely resembles decomposed trap that I at first sight supposed the beds of it to be decomposed lava flows interstratified with the nummulitic rocks. It may very probably consist of detritus derived from the trap.

occur, dipping at a very low angle to the north-west, and just west of them similar beds are seen dipping at 45° to the east, so that probably the line of fracture seen at Limbat extends across to Heerapoor. As usual in this country, scarcely any rock is seen except in the streams, and no continuous sections even there.

These beds of Heerapoor and Limbat contain, besides rolled agates, pebbles of sandstone, which are mostly subangular, and of laterite.

Section below Heerapoor.

Brown, gray and yellow sands, scarcely sufficiently coherent in general to deserve the name of sandstone, continue down the stream. With them there are interstratified occasional harder bands, with conglomerates and gravels, the latter frequently calcareous, and resembling the beds of Heerapoor. Near Singpoor a few fossils were found, chiefly Pectens, Oysters, a species of *Conus*, the club-shaped spines of a species of *Cidaris*, &c. No nummulites are met with. Below Singpoor are numerous fragments of limestone evidently derived from a thin bed. They abound in the valves of a species of Cirripede *(Balanus ?)*.

Rocks are seen at intervals down the stream till within about 2 miles of the place where it falls into the Nerbudda. Below Singpoor all are similar to the beds seen near Heerapoor and Limbat.

Between the Oomrawuttee and the Keem.

Between the Oomrawuttee and the Keem more rocks are exposed than between the streams further north. The dips are low, and the outcrop of the lower tertiary beds occupies a large space. A large portion of the basement beds here consist of laterite and nummulitic limestone, which are both largely exposed.

Laterite band near Whaliat.

A band of laterite, apparently identical in part with that of Wagulkhore, stretches across to Whaliat, and may thence be traced to the westward for 10 or 12 miles. At Whaliat it rises into small hills. In many places it has the usual

argillaceous structure and closely resembles decomposed trap impregnated with iron, in other places it is sandy. To the west, near Deenod, laterite also covers the surface, but a large portion of the superficial rock here has rather the appearance of a laterite gravel, such as occurs so frequently in the older alluvium of Bengal, reconstructed from the debris of the original rock. In many places fragments of conglomerate are seen.

Nummulitic limestone band near Whaliat.

This laterite may perhaps in places rest directly upon nummulitic limestone, a great band of which, probably of no great thickness, but occupying a considerable area, owing to its low dip, and the consequent breadth of its outcrops, stretches across south-south-east of the laterite, from south of Wagulkhore to near Deenod and Bhurn, about 14 miles. So few sections are seen at the surface throughout the long belt of rising ground formed by the laterite and limestone that no idea can be formed of their thickness. Probably other and softer beds are largely developed, but they do not crop out at the surface, and the hard fragments of limestone which resist denudation and are scattered over the ground convey the idea that the bed from which they are derived is of greater extent than is really the case. That other beds do occur is shewn close to Whaliat by the abundance of rolled agates, which indicate the presence of gravel or conglomerate between the limestone and the laterite.

Limestone near Dorwara.

A small patch of nummulitic limestone also crops out, apparently, in the middle of the laterite bed close to Dorwara. This may be the bed below the laterite brought up in a small anticlinal by a roll of the strata.

The limestone throughout abounds in *Nummulites*, and other *Foraminifera*. No rocks are clearly seen beneath it, but hard ferruginous sandstone and hard white calcareous sandy beds occur between Wagulkhore and Kaisurgam.

About half a mile south of Whaliat masses of red hæmatite, almost pure, abound scattered about the surface. They are probably derived from the laterite beds.

Balanus limestone.

Above the laterite, at Wattaria, pieces of the limestone with valves of *Balani*, like that seen near Singpoor on the Oomrawuttee stream, occur on the surface. Further to the south, at Boreedra, yellow argillaceous limestone is seen, and again to the north-west towards Khunode, sandy clays, gravels and conglomerates are met with. These are probably all the same beds which are seen in the Oomrawuttee.

Extension of rocks to westward.

These upper beds stretch hence across past Panolee, and as far as Elao, which is the most westwardly point where rocks occur between the Nerbudda and Taptee. Rock is seen here and there in the Keem, which passes just south of the belt of high land occupied by these beds. South of the Keem all is alluvium.

Section in Keem river.

The sections exposed in the Keem are all between Keemamlee and Elao, and always consist of the upper beds, agate conglomerates, more or less calcareous, and gravels, yellow sandy limestone, frequently nodular, and occasionally ferruginous sand.

Keemamlee.

The section at Keemamlee is just north of the village: in a bend of the river, yellow gritty conglomeritic sandstone is seen, dipping south-east at 10°. It is somewhat fossiliferous, containing *Oysters, Pectens, Balani,* some peculiar hemispherical bodies *(Bryozoa ?)* and spines of *Echinus;* all, however, being fragmentary.

Obha.

The next section seen is near Obha, where conglomerate and nodular calcareous beds, yellow in colour, interstratified with clays, dip west-south-west at about 3°. About half a mile east of the village crystals of gypsum abound in decomposed argillaceous beds.

Much rock occurs about Elao, but no good section is seen in the Keem, here a tidal river.

Elao.

South of all this western or lower portion of the Keem all is alluvium.

Nearly all the upper part of the Keem valley is also occupied by alluvium. In this a kind of *Unio* is sometimes found. No bones were observed. In two or three places laterite belonging to the nummulitics crops out from beneath the alluvial clays, but in general the traps are the first rocks to appear to the eastward. The principal exception is in the south branch of the Keem river near Timburwar. Here laterite appears, forming a small anticlinal; and ferruginous sandstone, containing dicotyledonous leaves, and some seeds, together with bluish clay, rests upon it.

Rocks in Upper Keem.

Below all this alluvium it is probable that the nummulitics roll over to the south, for the beds which come in about Sooralee dip nearly west, and are considerably south of the strike of those near Whaliat, which they so closely resemble in character as to render it most probable that they are a continuation of the same beds. The southerly dips seen to the west in the Keem near Elao are in favour of this.

Probable anticlinal.

Much nummulitic limestone and laterite are exposed east and south-east of the town of Turkesur. To the west of the town, rock occurs close to the surface throughout a considerable tract, but is rarely exposed. The dips are low.

Country east and south-east of Turkesur.

These rocks are first met with when proceeding southwards in a stream which joins the Keem from the south, and runs past the villages of Wustan, Sooralee and Nowgama. At Wustan trap occurs. Thence no rock is seen till near Sooralee, where yellow calcareous sandstone is met with, apparently nearly horizontal. At Nowgama a good section of a laterite bed of considerable thickness is exposed in the stream.

This laterite bed can be traced to the south, though occasionally concealed by cotton soil nearly as far as the Taptee river. About Turkesur the rocks are better seen than usual, and their order of succession appears to be the following :—(descending) :

General succession of lower tertiary beds near Turkesur.

I. Agate conglomerates and gravels, yellow calcareous sandstone, &c., occurring to the west of the town. No section seen; only fragments on the surface. These are upper beds like those of Singpoor, Heerapoor, &c.

II. *a.* Nummulitic limestone, seen in place at and about the town of Turkesur, and probably of considerable thickness. At the base, in one place; close to Turkesur, is seen some pipe clay, as at Wagulkhore.

b. Laterite, a massive bed, the same which is seen at Nowgama.

c. Nummulitic limestone, probably of no great thickness, 30 to 40 feet perhaps, but no section seen.

d. Agate gravel, containing masses of agate, rolled and unrolled, chert, &c.

e. Laterite, seen at Nerolee and Moonjhlao.

III. Trap.

No good section seen.

It is impossible to do more than guess at the thickness of these beds, scarcely any reliable dips or sections being seen. Little sections of a few yards in ditches, and pieces of stone scattered about the surface of the ground, are the sole indications of the existence of the different rocks, and these are only local. The uppermost nummulitic limestone is seen in massive blocks at Turkesur, and can thence be traced to the north in place for some distance, and then by loose blocks on the surface of the ground, nearly to Nowagam. South of Turkesur, it appears to be partly replaced

Localities where the different beds are seen.

by agate conglomerate near Roswar, but is again seen further south, near Nowagam, lying nearly horizontally. It is probably thinner there than near Turkesur, and

the agate conglomerate may very possibly rest unconformably upon it.

The laterite underneath is better traced. This is the Nowgama bed mentioned above. South of Nowgama it is ill seen for some distance, but afterwards is seen stretching across past Turkesur nearly as far as the Taptee.

The next bed in descending order, the lower band of nummulitic limestone, is well seen on the road from Turkesur south-east to Moonjhlao. It abounds in *Foraminifera*. A flat nummulite (*N. exponens?*) is very abundant, as is also *Orbitoides ephippium*, Sow., and *Orbitolites Mantelli*. *Nummulites obtusus*, Sow., or some closely allied species, also occurs.

Beneath this is a band, probably of some thickness, of agate gravel and conglomerate. No section of it is seen; its presence being indicated solely by rounded and unrounded agate pebbles at the surface, mixed with masses of chert. This bed occupies a hollow almost throughout the whole distance from the Keem to the Taptee. With the gravel there appear to be occasionally intercalated ferruginous sandstone and yellow sandy limestone. Agates are occasionally collected from this bed for the Cambay lapidaries.

Laterite of Nerolee, &c.

The lowest bed is a thick massive band of laterite. This commences abruptly on the north side of Nerolee village, no trace of it being found further to the north, and it forms a low ridge of hills running north and south. This bed is suddenly thrown about $\frac{3}{4}$ mile south of Nerolee, by a fault apparently with an east and west direction, and having a downthrow to the north. The ridge is thrown for a considerable distance, perhaps half a mile to the west, but continues on the south side of the fault past the village of Moonjhlao, where there is a slight break, and thence to the Taptee, about half way between the villages of Bhodan and Gulla.

In many places this well marked bed has a distinct dip to the west; at Moonjhlao the dip is 5°, and this is about the average.

This laterite throughout has the appearance of containing rounded and subangular fragments of decomposed ferruginous trap. The mass is a compact argillaceous and ferruginous rock, approaching claystone, sometimes mottled, rather pisolitic in structure, and with the characteristic glazed surface of laterite. The only rock anywhere seen to intervene between it and the trap is a white tufaceous looking argillaceous bed, resembling decomposed felspar, which underlies it at Nerolee.

Bed below laterite.

In the Taptee are some instructive sections of the tertiary beds, but they are not continuous. Passing down the right (north) bank of the river from Bhodan, very little trap is seen, though it is in place a little way back from the river's bank. About a mile from Bhodan, laterite is seen in the bank dipping to the west, and just east of this, trap is in place on the opposite (south) bank of the river. Below this nothing is seen in the river bank for about half a mile further, until, at the mouth of a small stream called the Rhen, the following section is seen:—(descending):

Sections in Taptee river.
Right bank below Bhodan.

Section at mouth of Rhen.

		Ft.	In.
1.	Laterite, about	10	0
2.	Yellow sandy calcareous rock, abounding in *Foraminifera*, especially *Orbitolites Mantelli*, D'Orb, and *Orbitoides ephippium*, Sow. ...	1	0
3.	Ditto softer	2	0
4.	Ditto same as 2	0	6
5.	Ditto softer and more sandy	2	0
6.	Ditto containing besides the *Foraminifera*, *Vulsella legumen* and species of *Bryozoa*	6	0
7.	Similar rock, but more calcareous; *Foraminifera* the same, but less abundant	0	6

Gulf of Cambay for the purpose of endeavouring to ascertain if the beds there existing, which, from their Mammalian fauna, are considered of miocene age by Falconer, presented any marked resemblance to the upper beds in the Oomrawuttee, Keem, and Taptee rivers, described in the preceding pages. Although the beds of Perim have been well described by several previous observers (see ante p. 6, &c.), a brief account of them in this place may be useful for comparison with the rocks to the eastward.

Object of visit to Perim.

Perim Island lies off the coast of Kathiawar near Gogo, and directly opposite to the mouth of the Nerbudda. It is simply a reef of rock, covered, in part, by blown sand, and, at high water, about 1½ miles long and barely half a mile broad, but far more extensive at low water. The greatest length is nearly from north to south (north by west to south by east), and the ridges of blown sand near the light-house on the west side of the island are nearly parallel to this (they run north 20 east-south 20 west).

Position of island and general character.

The rocks are best seen close to the southern extremity. The reef, dry at low water, and running out for a considerable distance on all sides of the island, is composed of irregular interstratifications of conglomerate and sandy clay. The sandy clay, best seen in the little cliff at the south end of the island, sections of which are given by Ethersey and Fulljames, is a thin bedded light grey sandy silt, abounding in "kunkur," the carbonate of lime in which may be derived from the overlying conglomerate. These silt beds closely resemble those seen in the Taptee near Gulla, those in the Ruttunpoor section, &c. The conglomerates belong to two forms, very distinct in appearance, but both containing bones.

Rocks of island.

That most prevalent is an extremely coarser ock, made up of rounded blocks of sandstone, varying from 3 feet in diameter downwards, but mostly not exceeding a foot, and very irregularly shaped. The sandstone is generally of fine texture, and grey or light brown in colour.

This conglomerate is nsually more or less nodular, and occasionally the bed appears chiefly made up of nodular concretionary pebbles, which, when weathered, strongly resemble casts of large univalve shells. The matrix of the pebbles which form the bulk of the rock is a coarse sandstone, containing small rounded fragments of agate and quartz, rarely exceeding an inch, and generally below ¼ inch in diameter.

The second principal variety is the same coarse sandstone with agate pebbles, the latter, however, being neither numerous nor conspicuous, without any of the rounded blocks of sandstone.

Both varieties appear to be calcareous; they are firm compact rocks and excellent building stones. The wall surrounding part of the island is built of them, and they have been largely quarried for grindstones, and also for exportation as building stones. The principal quay at Surat is also built of them.

In the conglomerates, besides bones, immense masses of fossil wood occur, very hard, heavy, and black, sometimes, but not always, having been bored by *Teredo*. No sandstone blocks bored by *Pholadidæ*, like those in the Taptee bed, could be found, although they were especially searched for.

In places fine sandstones occur, red or brown in colour, and generally in beds from 6 inches to a foot thick. Such beds, if consolidated and then broken up, might furnish the sub-angular blocks of the conglomerate.

The beds are in general horizontal. The sections given by Ethersey convey a fair idea of the strata in the low cliff at the south end of the island, but these beds are so variable that no two sections would be likely to give precisely the same result. It is doubtful if the strata be anywhere much disturbed. They appear to be steady on the cliff or to roll about on the reef, but the latter is probably due to unequal deposition and to the washing away of the soft clays.

8.	Unfossiliferous yellow ferruginous sand, containing grains of brown hæmatite	1	6
9.	Sand rock, also abounding in grains of brown hæmatite, more compact than the last, containing *Gasteropoda*, corals, and a few *Foraminifera*	0	6
10.	Ferruginous sand with but few fossils	1	9
11.	Sandy bed, rather less ferruginous, but still containing grains of brown hæmatite. In this bed occur bones, apparently of Mammalia,* numerous *Gasteropoda*, Pectens, Oysters, and other *Lamellibranchiata*, corals, and *Nummulites obtusus*, Sow., (or some species of similar form), but few other *Foraminifera* ...	8	0
12.	Laterite; (base not seen) about	10	0

The fossiliferous band is about 24 feet thick, and may be considered as a whole. The following fossils have been identified by Dr. Stoliczka from amongst those collected :—

Rostellaria Prestwichii, D'Orb.
Terebellum, sp.
Cerithium, sp.
Cypræa (Cypræovula) elegans, Lam.
Natica longispira, Leymerie.
Conus, sp., near C. brevis, Sow., but thinner.
Trochus, sp. (like T. mitratus, Desh.)
Pholas, sp.
Pecten Hopkinsi, D'Arch. and Haime.
P. Favrei., D'Arch.
P. corneus, Sow.
Vulsella legumen, D'Arch. and Haime.
Ostrea Flemingi, D'Arch.
O. lingua, Sow.
Hornera, sp. (near H. verrucosa, M. Ed.).
Echinanthus, fragments.

* The specimens obtained were fragments of ribs; they were not in a satisfactory state for comparison.

Cidaris spines and fragments of other Echinidæ.
Stylocœnia Vicaryi, M. Ed. and Haime.
Trochoseris ?
Trochocyathus Vandenbeckii, M. Ed. and Haime.
Nummulites perforata, D'Orb.
N. Brogniarti, D'Arch.
* N. exponens or N. spira (probably both).

Possibly nummulitic limestone again occurs beneath the section above detailed, for unrolled fragments are seen in abundance just east of the above beds in the Taptee. These may, however, have been carried up stream by an eddy when the river was in flood.

On leaving the section and going to the north for a few yards, trap is distinctly seen west of the uppermost laterite. Upon this trap laterite comes in again. The rocks in the section above quoted dip west 10° to 25° south, at an angle of about 7°; that is, they dip beneath the trap.

Apparent interstratification of trap and nummulitics.

At first this appeared to be a distinct case of interstratification of the uppermost traps with the nummulitics; and from the very trappean appearance of the laterites of Nowgama, Turkesur, &c., this conclusion was strengthened. But the evidence of enormous denudation of the traps in pre-nummulitic and nummulitic times seen about Ruttunpoor and elsewhere militated so strongly against this view that the Taptee section was re-examined, and it was found that the apparent superposition of a trap bed upon the nummulitic beds at the mouth of the Rhen might be explained by a fault.

Explained by a fault.

The laterite seen resting upon the trap to the west of the nummulitics is clearly a continuation of the bed so conspicuously seen at Nerolee and Moonjhlao. The nummulitics to the east (apparently beneath the trap) cannot certainly

* In this list *Orbitolites Mantelli* does not occur, nor *Orbitoides ephippium*. The latter certainly abounded in the upper part of the bed, and so, I think, did the shell to which the former name is applied by Dr. Carter. The specimens had probably been mislaid or separated from the *Gasteropoda*, &c.

PART III.

ECONOMIC GEOLOGY.

This will be a short chapter; with the exception of building stones, few minerals of value have been met with in Western India. Coal is entirely wanting throughout the tract under description; no trace of any of the rocks usually accompanying it having been anywhere seen where lower beds appear from beneath the trap.

Paucity of valuable minerals.

Iron.—The iron manufactured in the Dhar forest near Poonassa and Chandgurh has already been fully treated of by Dr. Oldham in the 2nd Volume of the Memoirs, p. 271. Some fine works were subsequently built by the Indian Government at Burwai under the superintendence of Mr. Mitander, a very able Swedish metallurgist. Every difficulty was overcome, and the works were perfectly ready for the manufacture of iron, when the Government, finding that additional European assistance was necessary in order to carry on the manufacture, declined to sanction any further expense, and offered the works for sale in 1864. Unfortunately, despite the great demand for iron throughout the country, no attempt has been made by any private person or public company to carry on the working.*

Burwai.

The ore at Burwai is found in irregular masses of breccia, the matrix of which is chiefly brown hæmatite, in the Bijawur series. It is not

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* It is, I think, a subject for regret that the small additional expense necessary was not sanctioned, and that the very great outlay upon the works should have been spent without deciding the question whether the iron manufacture *can* be carried on in India at a remunerative rate. It is also unfortunate that Mr. Mitander should have left India without an account of his various experiments, and the plans he adopted for burning and storage of charcoal, making fire bricks, (in which he completely succeeded), &c., being published in a form in which they would be useful to any one establishing iron works in India.

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clear that there is any distinct bed, but the ore is rich and found in several places.

Chandgurh.

The few furnaces which still exist around Chandgurh (the manufacture is fast dying out on account of the difficulty of procuring fuel) are similar in form and size to those employed in other parts of India, but differ in a few peculiarities. They are hollowed out of a bank (as in Bheerbhoom) and not built up, and are square inside, not round. They are about 5 feet high. The bellows used are worked by the hand.

Bagh.

Formerly there was a manufacture of iron at Bagh, but this has gradually disappeared from want of fuel. Dangerfield, in 1818, found three smelting furnaces and three forges at work. Now there are none, and there have been none for some years. The ores at Bagh were obtained from surface deposits, but the source is the same as at Burwai and Chandgurh, the highly ferruginous breccias of the Bijawur rocks. No iron works now exist in the western portions of the Satpoora hills. At Turkesur, however, close to Surat, are piles of iron slag marking the sites of old furnaces, although, so far as could be ascertained, there is no traditionary record, even amongst the natives, as to the date at which the manufacture occurred, and they appear totally ignorant of the source of the slag.

Turkesur.

Lime.—Limestone is by no means so abundant in the western portion of the Nerbudda valley as in the eastern. There is certainly much limestone in the Bijawurs, although it is usually too impure and too much mixed with silica be of use. About Chota Oodipoor there is a large quantity of crystalline limestone in the metamorphics, and some occurs here and there in the Champaneer beds.

Bijawurs.

Chota Oodipoor.

The uppermost bed of the Bagh group has been shown to be generally calcareous, and it is frequently sufficiently pure to be available for extracting lime.

Bagh beds.

Throughout the trap country limestone is in general wanting, except where beds of calcareous intertrappeans occur. These are only found near the base, and are in general wanting to the westward. A bed near Burwai afforded the best limestone for iron smelting that could be found in the neighbourhood. With this exception the only source of lime in the trap country is the kunkur, which abounds wherever there is a deep soil above the rocks, and especially in the larger masses of alluvial clay.

Trap country.

The nummulitic limestone affords excellent lime, and might, if a little less distant, be available for he supply of Bombay, where lime is greatly needed. It occurs in great quantities around Turkesur, near Surat.

Nummulitics.

Slate.—It is very difficult to judge of the quality of slate by what is seen at the surface, unless a very good section is exposed in a hill side, and this is not the case in the slates which occur between Soorajpoor and Jumbooghora, north-east of Baroda. So far as they are visible at the surface, however, they are promising. There are also some slates seen in the Bijawur beds, near Bagh, which might be available for many purposes, and some of which might perhaps be sufficiently homogeneous to be used for roofing, but they are less fine grained than those of the Champaneer beds.

Near Baroda.

Near Bagh.

Building Stones.—These abound. Many of the trap beds furnish admirable building stone, extremely tough, yet not excessively hard, quite free from joints and not liable to injury by exposure. At the same time some caution is necessary in selecting basaltic rocks for building purposes. None of the beds containing zeolites interspersed in irregular strings and veins throughout the mass are good. They are soft, brittle and liable to decompose. None of the ash beds are equal in strength, toughness, or resistance to the atmosphere, to the solid basalts, and no rock of a red colour should ever be taken for building purposes. It is almost always decomposed.

Trap.

Amongst the very best beds are the porphyritic basalts, such as those which form so large a proportion of the rocks on the Thull Ghat.

Nummulitic limestone.

In the nummulitics of Guzerat, the limestone appears well suited for building, but it is difficult to obtain it in large masses, or to trim it neatly. It is employed by the natives for bowries, temples, &c.; other compact calcareous beds being used for similar purposes.

Bagh beds.

In the Bagh beds there are some very good building stones. The massive sandstones of the Deva, and those which occur throughout the country to the south of Alleerajpoor and Bagh, would furnish excellent material. The gritty calcareous bed at the top, where it is not too cherty, would be well adapted for construction and could be easily worked.

Ellichpoor.

The rocks of undetermined age near Ellichpoor contain very good strong sandstone free from joints, hard and compact.

Vindhyans.

The Vindhyans contain some of the best building stone that can possibly be conceived. It is as hard and unalterable as any granite can possibly be, and many of the beds are by no means difficult to work. Others are too hard, but there are few places amongst these rocks where sandstones of many kinds, all admirably adapted for building, cannot be obtained.

Bijawurs, &c.

The lower rocks, Bijawurs, Champaneers, and the true metamorphics, yield stone of various qualities, but rarely as well adapted for building purposes as are those of the Bagh beds and Vindhyans.

Near Akola.

Salt.—*The salt obtained in the Poorna valley near Akola and Oomrawuttee is derived from brine, which is procured by sinking wells through the alluvium. The brine is very strong, and is evaporated to dryness by solar heat alone

* This account is from Mr. Wynne's note book.

in shallow pans, about 25 feet long and 5 feet wide. The floor of these is made of river gravel and of kunkur, beaten together into a concrete, and requires to be repaired and freshly beaten after each evaporation. Much salt is doubtless lost by percolation.

Mode of manufacture.

The wells are a little over 2 feet 6 inches wide, and lined with wicker work. An earthern vessel with a wide mouth is used to draw the brine, and the pans are filled to a depth of about 3 inches. They evaporate to dryness in about 12 days in the cold weather, and in 8 days in the hot season, yielding 2 seers of salt in the former, but more in the latter, probably from the loss by percolation being less. Each well produces about a kandi, or 20 maunds of salt, per month. Manual labour alone is employed in working the wells.

It is by no means impossible that clay containing salt may exist at considerable depths beneath the alluvium of Khandeish and of the Nerbudda plain, but such is not positively known to be the case.

Agates, Cornelian, Jasper and other Ornamental Stones.—Agates and jasper of various kinds are largely yielded by the trap rocks; they are collected in various parts of the country and cut by the lapidaries of Cambay, Jubbulpoor, &c. The only place, however, where any regular workings take place are amongst the gravels of the tertiary rocks, many beds of which consist entirely of agates derived from the traps. The principal of these workings are near Ruttunpoor, 13 miles east of Broach.

Ruttunpoor mines.

The only agates considered of any value occur in a thin ferruginous bed, not exceeding a foot in thickness, to the iron in which is probably due the colour which gives the stones their value. The pits worked vary of course with the depth of the stratum; those examined by the survey were about 30 feet deep, and the miners descended by foot holes in the sides. Beneath, the usual rabbit warren style, so prevalent in Indian mining, and chiefly remarkable for the utter absence of anything like system, was employed to dig

away portions of the agate bed. The holes were barely large enough for a man to get through squatting, *more Indico*, or on all-fours. The process for developing the colour of the agates has been described by Mr. Copeland.* The agates are chipped at the mine, and those considered good are taken to Ruttunpoor and exposed to the sun. They are subsequently burned in earthern pots and then chipped again to ascertain if they are properly coloured, after which they are sold to the lapidaries.

The mines fall in during the monsoon, when they are not worked. They are rented by the Rajpeepla Raja to a Mussalman of Cambay for Rs. 3,000 a year. Formerly they are said to have produced more.

Some agates are obtained from other beds, or picked up in the nullahs, but the greater portion are derived from the Ruttunpoor mines.

* Trans. Lit. Soc., Bombay, Vol. I, p. 289: Geological Papers on Western India, p. 491.

APPENDIX.

List of papers relating to the Nerbudda and Taptee valleys, and adjoining districts, including Eastern Guzerat, and East and West Berar, in addition to those on the district of the Nerbudda, of which a list was given in Vol. II of these Memoirs, pp. 337-341.

1815. COPELAND, J., Esq.—* Account of the cornelian mines in the neighbourhood of Broach. Trans. Lity. Soc., Bombay, Vol. I, p. 289.

1818. DANGERFIELD, CAPTAIN F.—Some account of the caves of Bagh, called the Panch Pandoos. *Ibid.*, Vol. II, p. 194. (Principally descriptive, but contains some remarks on the geology and on the iron smelting then carried on at Bagh).

1821. STEWART, CAPTAIN JOHN.—Geological notes on the strata between Malwa and Guzerat. *Ibid.*, Vol. III, p. 538.

1822. FRASER, JAS. B., Esq.—Description accompanying a collection of specimens made on a journey from Delhi to Bombay. Geological Trans., Ser. 2, Vol. I, p. 141. Remarks on the preceding paper by the Secretaries, p. 155.

1833. VOYSEY, DR. H. W.—* On some petrified shells found in the Gawilgurh range of hills. Asiatic Researches, Vol. XVIII, p. 189.

1834. JENKINS, CAPTAIN F.—An account of some minerals collected at Nagpur and its vicinity, with remarks on the geology, &c., of that part of the country. Asiatic Researches, Vol. XVIII, p. 195.

" MILES, LIEUT. R. H.—Some remarks upon the country to the south-west of Hoshungabad, &c. J. A. S., Beng., Vol. III, p. 61.

1836. HÜGEL, BARON.—Recent discovery of fossil bones in Perim Island. J. A. S., Beng., Vol. V, p. 288.

" FULLJAMES, LIEUT. GEO.— Ditto ditto ditto.

" LUSH, DR. CHARLES.—Geological notes on the Northern Concan, and a small portion of Guzerat and Kattywar. J. A. S., Beng., Vol. V, p. 761.

1838. DE L'HOSTE, LIEUT. E. P.—On the Nerbudda river. Trans. Bombay Geog. Soc., Vol. I, p. 174. (Chiefly relating to the navigation of the river).

" ETHERSEY, LIEUT. R.—* Note on Perim Island in the gulf of Cambay. Trans. Bombay Geog. Soc., Vol. II, p. 55.

N. B.—Those marked thus * are also printed in the Geological Papers on "Western India."

1838. Fulljames, Lieut. G.—A visit in December 1832 to the cornelian mines situated in the Rajpeepla hills to the eastward of Broach. *Ibid.*, II, p. 74.

1841. Stirling, Major W.—A visit to the falls of Sansadurra. Trans. Bombay Geog. Soc., Vol. for Sept. 1841 to May 1844, p. 5.

„ Ditto.—Notice of granite protruding through the trap in the bed of the river Nerbudda at Mundleysir. *Ibid.*, p. 7.

1844. Malcolmson, Dr. J. G.—Note on Lacusterine Tertiary Fossils from the Vindhyan mountains near Mandoo, and on the period of the elevation of that chain. Trans. Bombay Geog. Soc., Vol. V, p. 368.

„ Nicholson, Dr.—On the island of Perim. Jour. Bombay Br. R. A. S., Vol. I, p. 10.

1845. Falconer, Dr. H.—* Description of some fossil remains of Dinotherium, Giraffe, and other mammalia from the gulf of Cambay in India. Quart. Jour. Geol. Soc., Vol. I, p. 356.

„ Bradley, Dr. W. H.—Some account of the topography and climate of Chiculda situated on the table land of the Gawil Range. Trans. Bombay Geog. Soc., Vol. VII, p. 167.

„ Abbott, Captain J.—Account of certain agate splinters found in the clay stratum bordering the river Nerbudda. J. A. S., Beng., Vol. XIV, p. 756.

„ Bettington, Albemarle.—Memorandum on certain fossils, more particularly a new ruminant found at the island of Perim, in the gulf of Cambay. Jour. Roy. As. Soc., London, Vol. VIII, p. 340.
Note on ditto, by Prof. Owen. *Ibid*, p. 417.

1849. Rigby, Lieut. C. P.—Report on Torun Mul in the Satpoora mountains. Trans. Bombay Geog. Soc., Vol. IX, p. 1.

1851. Hay, Captain.—Report on the Turan Mull Hill. J. A. S., Beng., Vol. XX, p. 502.

1855. Buist, Dr. G.—Notes on a journey through parts of Kattywar and Guzerat. Trans. Bombay Geog. Soc., Vol. XIII, p. 11.

1856. Impey, E., Esq.—Description of the caves of Bagh in Rath. Jour. Bombay Br. R. A. S., Vol. V, p. 543.

1858. Oldham, T., Esq.—On some additions to our knowledge of the cretaceous beds of India. J. A. S., Beng., Vol. XXVII, p. 112.

1861. Rogers, A., Esq.—Discovery of nummulitic limestone in situ at Turkesur. Jour. Bombay Br. R. A. S., Vol. VI, p. 164.

On the occurrence of FROG-BEDS *at a locality hitherto concealed, but exposed now by reclamation works in* BOMBAY ISLAND, *December* 1867; *by* A. B. WYNNE F. G. S., *Geological Survey of India.*

Since the examination which furnished data for the report on the geology of Bombay Island, extensive operations for the reclamation of the foreshore of Back Bay have laid open a large space on the east flank of Malabar Hill, exhibiting its structure from its foot for a considerable distance upwards, and thus confirming the view already offered of the arrangement of the rocks.

The excavation, which is about 350 yards in length and 140 feet in depth, is situated at Chaopattee (see page 47, Report Geology, Bombay Island, Mem., Geol. Survey, India, Vol. V), near the north-west corner of the Bay. Its place in the frontispiece of the report would be behind the Cotton Factory, the smoke from which is so conspicuous, and more distant by about a mile.

The site, which was chosen chiefly from its vicinity to the shore to be reclaimed, proved fortunate, as the soft band beneath the hill is locally thick, and instead of encountering the hard basalt, blocks of which from above were strewn over the slope, the ashy beds and associated shales afforded materials much more easily extracted and well calculated for forming the embankment when faced with blocks of the basalt. This good fortune, however, appears to have been unforeseen. The base of the hill was covered with detritus. Its true structure was not generally known, and if the then recorded observations had been relied upon, only a thin band of shales extending horizontally beneath the hill would have been expected to occur.

The soft band so well seen in this excavation consists of muddy and ashy rock with intercalated layers of shale. Of these the lowest are hard dark gray or bluish argillaceous rocks with thin black shaly partings occurring as a band, of some two to three feet in thickness. The surface

of the gray trap upon which they have been deposited, and which is seen at the bottom of the quarry, is uneven, having great lumpy protuberances interrupting the extension of the shales. At a little distance above the lower band, a considerably thicker one without any marked boundary occurs, being apparently merely a shaly condition of the ashy rock. It is flaggy in places, very thinly laminated; when damp somewhat flexible, papyraceous, and its colour is a dull olive, proceeding apparently from decomposition. The whole of these soft portions of the rocks seen have a look of irregularity, and the upper part beneath the basalt which caps the hill is of a soft reddish rusty and friable nature.

In the lowest or darker shales the best preserved specimens of the *Rana pusilla*, Owen, have been found associated with ribbed fragments of plants and larger, but generally shapeless, pieces of carbonised vegetable organisms almost devoid of structure. The frog skeletons are numerous, being seen on some slabs scattered over the surface at intervals of from one to eight or nine inches in all kinds of postures; the hind legs extended, crossed, contracted, or twisted; the other limbs are less frequently preserved. In the upper band the skeletons are even more numerous, relieved in black against the lighter color of the rock; this, though somewhat coherent at first, soon becomes so separated and fragile that preservation of the specimens is difficult. In one instance only part of a skeleton was seen replaced with a white mineral, perhaps carbonate of lime, but the small size of the skeletons, usually about 1¼ inches in length, prevented recognition.

Frog-beds do not occur in the upper portion of the soft band, which is, however, too intimately associated with the shales to be separated, and the whole group may be stated to average somewhat less than 100 feet in thickness.

The height of Malabar Hill at this place appears to have been understated; judging from the measurement of the ashy and shale group, it must be rather over 200 feet instead of 180, and may be more nearly 230 feet.

Osteological notes on OXYGLOSSUS PUSILLUS, *(Rana pusilla,* Owen), *from the tertiary frog-beds in the Island of Bombay ; by* FERD. STOLICZKA, PH. D., F. G. S., *Palæontologist of the Geological Survey of India.*

In the preceding note, Mr. A. B. Wynne has described the stratigraphical position of some recently discovered frog-beds which were not exposed, when two years since he described these deposits in greater detail (Mem. Geol. Survey of India, Vol. V, p. 173, 1866). The small Batrachia occurring in these beds have been known for more than twenty years; they were first characterized by Prof. R. Owen under the name of *Rana pusilla* (Quar. Jour. Geol. Soc., Lond., Vol. III, p. 224, 1847). The Geological Survey of India has obtained a large number of well preserved specimens during Mr. Wynne's recent researches, and the examination of these has led me to alter the generic determination of these fossils, the reasons for which change will become more evident as I proceed.

I shall give a brief sketch of the osteology of the species, comparing some of the most important points in the structure of these fossils, and of some of the living representatives of the same genus, and will also refer shortly to the other organic remains associated with these Batrachians.

OXYGLOSSUS PUSILLUS, *Owen*, sp. (Pl. IX).

1. *Head* large, subtriangular, posteriorly about one-fourth broader than long, anteriorly obtusely rounded (see fig. 3). The intermaxillaries *(im)* are comparatively large, posteriorly at their junction, with short pointed processes; both the intermaxillaries and the maxillaries *(m)* are armed with long subequal teeth. The nasals, frontals, parietals, and occipitals are united to a single long and broad bone, without being distinguishable in any of the specimens examined. A small space between the processes of the intermaxillaries and the nasals must have remained imperfectly ossified, and consequently the intermaxillaries became very often dislodged. The anterior prolongations of the frontals *(fr)* appear to be perfectly ossified, and united to the corresponding processes of the

maxillaries *(m)*. From the lateral branching of the frontals, a slight furrow is traceable in the upper view of the occipital bones (fig. 3), running posteriorly near the lateral margins: it disappears afterwards, and two narrow ridges are seen converging posteriorly where the occipital *(o)* should be placed. The tympanic bones *(tm)* are thick, the jugal *(j)* rather thin: they do not appear, so far as they are seen, to differ from the corresponding bones in the recent species of *Ranidæ*.

The lower jaw (fig. 2, *l*) consists of a narrow bone without teeth, nor is there any trace of vomerine teeth observable. The absence of these is the chief distinction between *Oxyglossus* and *Rana*.

2. The *vertebral column* consists of vertebræ, which are of the usual form, broader than long, with very short neural spines, minute posterior zygapophyses, and the diapophyses of various length. The atlas (no. 1 in fig. 1 or *cd* in fig. 3) has, as usually, no diapophysis, but is laterally rather sharply pointed; the diapophyses of the third vertebræ are longer than any of the others, although very slightly longer than those of the second: those of the fifth vertebra are subequal to the fourth. The diapophyses of the succeeding vertebræ rapidly shorten, being nearly of equal length,—about equal to one-half of those of the third vertebra. The sacral vertebra is prolonged into a strong coccygeal style *(co)*, slightly expanded a little below its junction with the sacral vertebra, and then gradually narrowing posteriorly; it appears to have had a sharp ridge above, and its length equals two-thirds of that of the vertebral column. The diapophyses of the last vertebræ are club-shaped, considerably thicker externally where the ilia *(il)* join. These are two long, laterally compressed bones of about equal thickness, very slightly bent externally, posteriorly united to the ischia, which project a little behind *(i)*. At the junction of the iliac and ischiac bones, the former are slightly thicker, but the joints for the femora do not project laterally.

3. *Anterior extremities and their appendages.*—The total length of the anterior extremity is three-fifths of that of the body, the length of this being almost equal to that of the humerus, the anchylosed ulna

and radius, together with the carpal bones. The humerus and the united ulna and radius *(h* and *ur)* are rather thick in proportion to their length, (the former being a little longer). The carpal bones *(ca)* appear to be only five (? 6) ; the outer one the (lunar) is the largest, the others are not quite sufficiently distinctly discernible. The carpal bones give support to four subequal metacarpal bones (see fig. 5), there being only a trace of the thumb perceptible: the index and middle finger have, as usually, two phalanges: the next finger (which is the longest) three phalanges, as has also the fifth digit, though considerably shorter than the last.

The lower portion of the scapula (fig. 1, *s*) is broad and short; of the upper portion only the posterior subcylindrical margin is preserved; the rest does not appear to have been perfectly ossified. The clavicle and coracoid *(cl* and *co)*, both of which are distinctly visible in the ventral view (fig. 2), run parallel and very close to each other; the former is very thin, perfectly ossified and united in the pectral line, the outer ends being curved forward and joining the scapula by an oblique, lateral and very narrow articulation. The coracoid is more flattened and broader towards each end than in the middle. Of the sternal bones nothing could be seen; they were probably not ossified.

4. *Posterior extremities.*—The hind limbs each exceed the total length of the body by one-third; the femur (fig. 1, *f*) and the anchylosed tibia and fibula are two cylindrical bones, thinner in the middle than towards their ends. The femur is nearly quite as long as the united tibia and fibula, and their length together equals that of the vertebral column. The calcaneus and astragalus (*cc* and *a* in figs. 1 and 4), the latter being a very slender and twisted bone, are half as long as the tibia. Of the tarsal bones (fig. 4), the cuboid *(c)* is transversally much elongated and compressed; the naviculare *(n)* is hardly one-third of the size of the former ; then follow two bones, *(ab)* the one next to the cuboid being much longer, the other very small; to this last one joins a still smaller

bone which gives support to a rather elongated ossified spur, *(sp)* projecting on the internal side of the tarsal bones. The metatarsal bones *(mt)* are five, the first being the shortest; the second half the length of the fourth, which is the longest; and the third and fifth are equal, or very nearly so. The first supports two very short phalanges, the second equally so, but the phalanges are a little longer; the third and fifth have three and the fourth has four phalanges. From the way in which the toes are generally placed close together, it is very probable that they were united by a web reaching very nearly to their tips.

The following are the mean measurements of a large number of specimens as regards the various bones, and I add some of the measurements of a recent species of the same genus :—

	Oxyglossus pusillus, Owen.		*Oxyglossus lævis*, Gray (recent).	
Total length of the body,	$\frac{28}{40}$	of an inch	... ... $1\frac{2}{40}$	of an inch.
Length of the head,	$\frac{7}{40}$	„	... ... $1\frac{1}{40}$	„
Posterior width of the head,	$\frac{18}{40}$	„	... ... $\frac{14}{40}$	„
Length of the sacral vertebra, including the ilia and ischia	$\frac{11}{40}$	„	... ... $\frac{18}{40}$	„
Length of humerus,	$\frac{8}{40}$	„	... ... $\frac{9}{40}$	„
„ ulna and radius,	$\frac{4}{40}$	„	... ... $\frac{7}{40}$	„
„ 4th metacarpal bone, a little more than	$\frac{3}{40}$	„	a little more than ... $\frac{3}{4}$	„
„ femur,	$\frac{8}{40}$	„	... ... $\frac{14}{40}$	„
„ tibia and fibula,	$\frac{10}{40}$	„	... ... $\frac{17}{40}$	„
„ calcaneus and astragalus,	$\frac{4}{40}$	„	... ... $\frac{8}{40}$	„
„ 4th metatarsal bone,	$\frac{4}{40}$	„	... ... $\frac{8}{40}$	„
Total length of anterior extremity,	$\frac{18}{40}$	„	... ... $\frac{28}{40}$	„
„ posterior extremity,	$\frac{38}{40}$	„	... ... $1\frac{18}{40}$	„

From these short and general osteological remarks it is evident that the fossil in question belongs to the *Ranidæ*, as first pointed out by Prof. Owen. There are actually no essential distinctions traceable in any of the details of our skeletons from those of the *Ranidæ*. The want of vomerine teeth, however, characterizes the fossil species as an *Oxyglossus* and not

as a *Rana*. Both genera are in many other respects closely allied, still there are a few other points to be noticed which tend to support the generic determination of the fossil species.

The genus *Oxyglossus* was initiated by Tschudi for a species, *O. lima*, which is found along the coast of Siam and China. Dumeril and Bibron (Herpetologie VIII, p. 335,) state that it was also brought by Belanger from Bengal, which is not very improbable. Günther (Reptiles of India, 1864, p. 401,) states that he had never seen a specimen of *O. lima* larger than 1½ inches long. Gray described in the catalogue of the Batrachia Salientia, 1858, p. 6, a second species, *O. lævis*, which is said to occur only in the Philippines. I am not acquainted with any more species of that genus; of the second, however, I was fortunate in being able to examine a few specimens. The locality of these is unknown, but as there were in the Museum of the Asiatic Society of Bengal hardly any reptiles from the Philippines, it is rather likely that the specimens are Indian. They only differ from Gray's type by the want of the few brown spots on the throat; the presence or want of the median dorsal stripe is, as in many other *Ranidæ*, not a constant specific character.

Comparing now the large size of the head of the fossil species, its proportions certainly resemble more those of the recent *Oxyglossus* than those of *Rana* proper. The comparative shortness of the calcaneus and astragalus (being hardly more than half the length of the femur), and the comparatively greater length of the bones forming the ulna and radius (not being much shorter than the humerus), characterize the fossil as a species, the salient power of which was less developed than in most of the species of true *Rana*. The intermaxillaries are also in proportion generally broader in *Oxyglossus* than they are in *Rana*. The diapophyses of the sacral vertebræ are in the former club-shaped, as in the fossil species, not cylindrical, as usually in the latter.

All the specimens which I have examined are such as have completed their metamorphosis, and are mostly of the same, or very nearly the same,

small size, as has been already noticed by Prof. Owen. The very large number of specimens found together shews sufficiently that *Oxyglossus pusillus* must have been living gregariously in a swamp, and was really a very small species of frogs, as both the recent *Oxyglossus* decidedly are. The latter are likewise peculiar insular forms, but whether the suggestion regarding the habits of the fossil *Oxyglossus* coincides with those of the recent species, I am unfortunately not in a position to state, for nothing appears to have been recorded of the habits of the two living species of *Oxyglossus*. Of the largest specimen of *Oxyglossus lævis* which I observed, the measurements are given above; it seems hardly to attain the size of *O. lima*, taking Günther's measurement as the mean.

I may notice that the recent species of *Ixulus*, Dum. and Bibr., are also characterized by the want of vomerine teeth, but the proportions of the limbs and the mode of occurrence do not make it in the least probable that our fossil belonged to the group of tree-frogs. Somewhat similar objections regarding the habitat also apply to the genus *Dicroglossus*, Günther, which is based upon a Hymalayan species, also without vomerine teeth. The fore and hind extremities in the only known species, *Dicrog. Adolfi*, appear in proportion to the body longer (see Günther's Indian Reptiles, p. 402), than they are in either of the known species of *Oxyglossus*.

Associated with *Oxyglossus pusillus*, which occurs in a black or brownish sandy shale (the former, undoubtedly, very highly impregnated with organic matter) were found small specimens of wood, and fragmentary impressions of long narrow leaves of a plant which was probably a species of *Typha*, usually growing in swamps. Besides these very numerous impressions of *Cypridinæ* were observed, but they are so indistinct as not even to admit of a generic determination. Not a trace of a fish, not even a single scale, has, remarkably enough, been noticed.

The manner in which the entire skeletons of *Oxygl. pusillus* are usually found shews that most of the specimens must have met with a quick death, and that they were buried shortly afterwards in the muddy

soil of the swamps, before the muscular and ligamentary parts of the body could decompose. Most likely, volcanic action and the flows of lava streams were the agents which caused the rapid destruction of the little life that existed in their neighbourhood. Storms and winds were also most likely in operation then as they are now, for some of the specimens give direct indications on the rock that they have been dragged along the surface of the soft mud for various distances (see fig. 6 on pl. IX). The fine stripes on the surface, the tracks which the body left on it,—being a little deeper where they correspond to the thickened joints of the body,—are distinctly traceable. No force acting on a special part of the body of the frog could produce this, for it would have certainly dislodged the corresponding position of the various bones. It could have been only one which acted upon the whole body equally strongly, without injuring any part of it, and that was apparently only the motion of the atmosphere. The surface of the rock is generally smooth, and only occasionally appears so little disturbed, that it would seem more difficult to explain the dragging motion of the dead specimens by a temporary upheaval of the strata. Besides, if such had been the case, the motion of the specimens would most likely be a more general one, while in reality the marks (see fig. 6) appear to be rarely found, and are certainly not traceable on six other specimens of the same species of frog, lying on the same surface of the slab beside the one figured.

For further geological details, I must refer the reader to Mr. Wynne's interesting account of these deposits in his paper on the geology in the Island of Bombay, (loc. cit., p. 217, etc.).

Explanation of Plate IX.

Fig. 1. A complete skeleton, drawn to double the natural dimensions; dorsal view.

Fig. 2. Ventral view of the head, the first three vertebræ, humerus and breast bones; drawn to twice the natural dimensions.

Fig. 3. Upper view of the exact form of the head, drawn in three times of the natural dimensions.

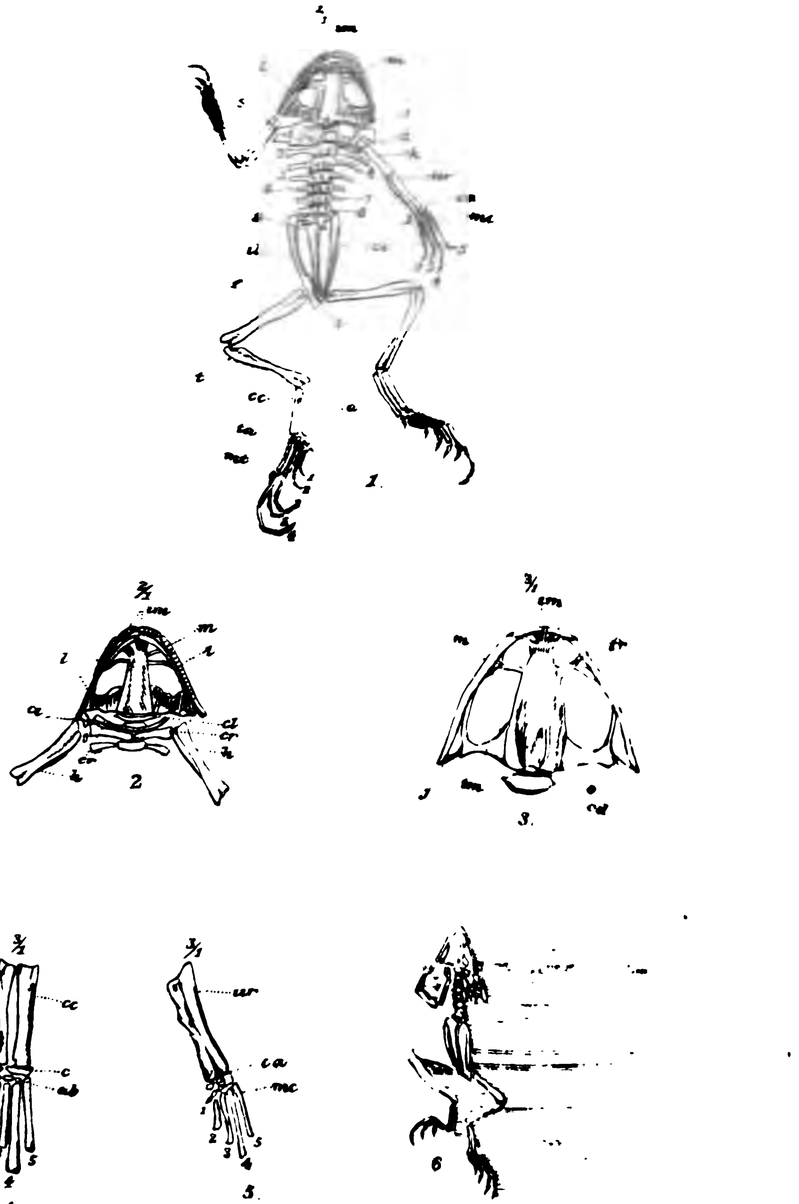
Fig. 4. Calcaneus and astragalus, tarsal and metatarsal bones; three times natural size.

Fig. 5. Ulna and radius with carpal and metacarpal bones; also in three times of the natural size.

Fig. 6. A specimen in natural size, shewing the peculiar lines, described on the previous page.

Signification of the various letters in the plate.

m,	maxillary.	*t*,	tibia and fibula.
im,	intermaxillaries.	*cc*,	calcaneus.
l,	lower jaw.	*a*,	astragalus.
s,	scapula.	*ta*,	tarsal bones.
1,	atlas. } vertebral column.	*mt*,	metatarsal bones.
2-8,	abdominal vertebræ, } vertebral column.	*c*,	cuboid.
9,	sacral vertebra, } vertebral column.	*n*,	naviculare.
co,	coccygeal style.	*ab*,	two lower tarsal bones.
il,	*ilia*.	*sp*,	spur and toe-bone.
i,	Posterior prolongation of the ischiac bones.	1-5,	toes, in fig. 1.
h,	humerus.	*cr*,	coracoid, } in fig. 2.
ur,	ulna and radius.	*cl*,	clavicula, } in fig. 2.
ca,	carpal bones.	*cd*,	atlas, } in fig. 3.
mc,	metacarpal bones.	*fr*,	frontals, } in fig. 3.
1-5,	fingers, in fig. 1.	*j*,	jugal bones, } in fig. 3.
f,	femur.	*tm*,	tympanic bones, } in fig. 3.
		o,	occypital region, } in fig. 3.



Oxyglossus pusillus, Owen, sp.